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Monte Carlo Calculations for Evaluating the Boundary Layer Illumination and Radiation Balance Model

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Wells Consulting, Inc.

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13. ABSTRACT *(Maximum 200 words)*

The AGGIE Monte Carlo code was used to provide data on the leakage of photons from the six sides of a Boundary Layer Illumination Radiation Model (BLIRB) space containing one or more clouds. The leakage data are to be used to evaluate the results of similar calculations by BLIRB. The data to be generated by the AGGIE code were for three scenarios. Scenario 1 defined a simple 3-D BLIRB space. The region outside of the BLIRB space was treated as a vacuum in each of the scenarios. The second scenario simulates the shadowing effect one cloud has on another cloud. The third scenario defines a waffle geometry in which the scattering medium is squashed in one direction, resulting in an aspect ratio of 10:1. The AGGIE results, giving the fraction of the incident photons that leak out of each of the six sides of the BLIRB space for each scenario, are listed in tables and plotted in figures, where they are compared with simular calculations by the BLIRB code.

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1. Introduction

A Generalized Geometry Irradiance Estimator (AGGIE) Monte Carlo code described by Wells (1995) was used to provide data for evaluating the Boundary Layer Illumination Radiation Model (BLIRB) (Zardecki 1995). BLIRB is a part of the Low Observable Atmospheric Effects Model now used by the Battlefield Environment Directorate (BED) at White Sands Missile Range. Three scenarios were defined for the AGGIE calculations by Dr. Patti Gillespie, Dr. Allen Wetmore, and David Tofsted of BED.

Scenario 1 describes a simple three dimensional (3-D) scenario (a 5- by 5-km cubical cloud) (figure 1), in which the BLIRB space is filled with a homogeneous scattering medium. The scattering medium is described by a Henyey-Greenstein phase function with asymmetry parameter g = 0.75. The region outside of the BLIRB space is treated as a vacuum. AGGIE calculations were made for incident zenith angles of 0.0° and 84.3° and for extinction coefficients of 0.2, 1.0, 2.0, 3.0, 5.0, and 10.0 1/km. When the source radiation is incident normal to the BLIRB space for scenario 1, the source area is the area defining the top of the BLIRB space. When the source radiation is incident at a zenith angle of 84.3°, the source area is the top of the BLIRB space plus the area shown in figure 1 defined by the distance A. For a source zenith angle of 84.3°, the source area is given by

$$Source\ area = 25 + 25*TAN(84.3) = 275.4677\ (km*km). \quad (1)$$

The source radiation is uniformly distributed over the source area and its azimuthal direction is parallel to the +X axis. When the source zenith angle is 84.3°, the fraction of the source radiation that enters the XY plane at X = 0.0 is 0.909245 and the fraction of the source radiation entering the top of the cloud is 0.090755.

The results obtained from the AGGIE runs for scenario 1 are described in section 2 where they are compared with BLIRB data (Wells 1995).

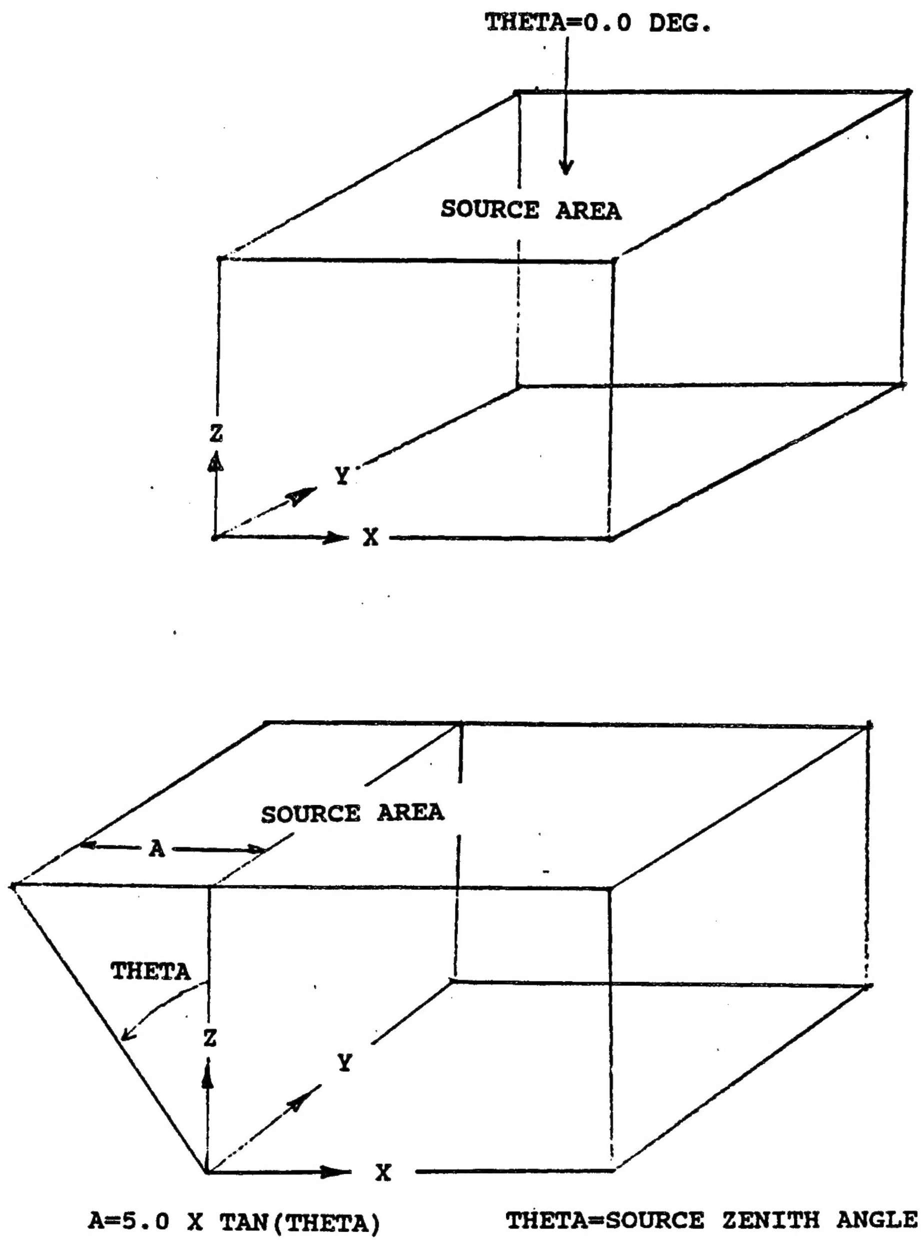

Figure 1. Scenario 1 geometry for case where the zenith angle is 0.0° and greater than 0.0°.

Scenario 2 simulates the shadowing effect one cloud has on another cloud. The BLIRB space is a cube with 5-km edges. The BLIRB space contains two cuboidal clouds. The diagonally-opposite vertices of the BLIRB space are (0,0,0) and (5,5,5) km. The two cuboidal clouds contained in the BLIRB space (figure 2) are assumed to be composed of the same Henyey-Greenstein medium with an asymmetry parameter g = 0.75 and a single scattering albedo of 0.9. The diagonally opposite vertices of the first cloud are given by coordinates (1,1,1) and (2,4,3) km. The vertices for the second cloud are (3,1,2) and (4,4,4) km. Figure 2 illustrates the projection of the two clouds on the plane containing the X and Y axes. Figure 2 also shows the projection of the two clouds on the plane containing the X and Z axes. When the zenith angle of incidence is 0.0°, the source radiation is incident to the top of the BLIRB space containing the clouds (Z = 5-km plane). When the source zenith angle is 30°, the source radiation enters the cloud through both the top of the BLIRB space (Z = 5-km plane) and the X = 5-km plane (side 2 of the BLIRB space). The regions within the BLIRB space not occupied by the two clouds were considered to be a vacuum, with neither scattering or absorption. The extinction coefficients used for the AGGIE runs for scenario 2 are 1, 5, 10, and 25 1/km.

Additional AGGIE calculations were run for the case where the zenith angle was 30°. In those calculations, the source area extended from X = 0.0 km to X = 5.0+A. The azimuthal direction of the incident radiation was 180° so that the source radiation was incident to the top (side 6) and side 2 of the BLIRB space. For these calculations, the extinction coefficients used for the two clouds within the BLIRB space were 1.0, 5.0, 10.0, and 25.0 1/km. The results from the AGGIE calculations for scenario 2 are presented in section 3, where they are also compared with similar results from BLIRB calculations reported by Wells (1995).

Scenario 3 deals with a waffle geometry in which the scattering medium is squashed in one direction, resulting in an aspect ratio of 10:1. The BLIRB space is 50 by 50 km in horizontal extent and 5-km high. The cloud occupies all of the BLIRB space. The region outside of the BLIRB space is treated as a vacuum. The geometry for scenario 3 is similar to that illustrated in figure 1 except that XMIN = 0.0, XMAX = 50 km, YMIN = 0.0, YMAX = 50 km, ZMIN = 0.0, and ZMAX = 5 km.

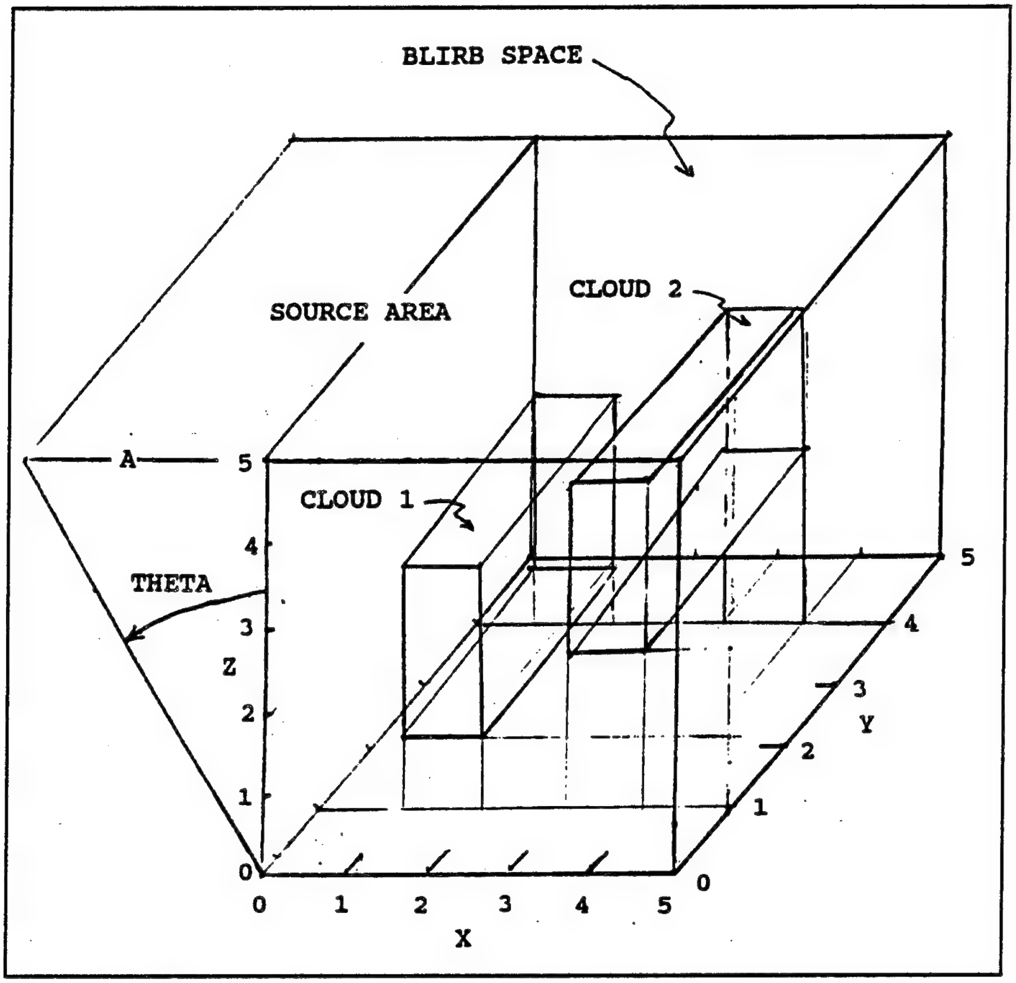

Figure 2. Scenario 2 geometry.

The source area when the zenith angle is greater than 0.0° is given by equation (2):

$$\textit{Source area} = 50*50 + 50*50TAN(\Theta). \tag{2}$$

Two series of AGGIE calculations were run. In the first case, a homogenous cloud with a Henyey-Greenstein phase function having an asymmetry parameter of g = .75 and a single scattering albedo of 0.9 was considered. In the second case, all of the parameters were the same except the asymmetry parameter had a value of g = 0.0 (isotropic scattering). The results of the AGGIE calculations are described in section 4 where they are also compared with BLIRB results reported by Wells (1995).

The side numbers for the BLIRB spaces for scenarios 1, 2, and 3 are defined as follows:

- Side 1 is the area defined on the YZ plane at X = 0.0 km.

- Side 2 is the area defined on the YZ plane at X = 5.0 km for scenarios 1 and 2 and at X = 50 km for scenario 3.

- Side 3 is the area defined on the XZ plane at Y = 0.0 km.

- Side 4 is the area defined on the XZ plane at Y = 5.0 km for scenarios 1 and 2 and at Y = 50 km for scenario 3.

- Side 5 is the area on the bottom of the BLIRB space at Z = 0.0 km.

- Side 6 is the area on the top of the BLIRB space at Z = 5.0 km.

2. AGGIE Calculations for Scenario 1

Figure 1 shows the two geometries used in the AGGIE calculations for scenario 1 when the source zenith was 0.0° and 84.3°. When the zenith angle is 0.0°, the source is incident only to side 6 (the top) of the BLIRB space. The source area is 25 km*km. When the source zenith angle is 84.3°, the source area is given by the equation

$$\textit{Source area} = 5.0(A + 5.0) \tag{3}$$

where

$$A = 5.0 \text{ Tan } (84.3) = 50.09354 \text{ km.}$$

The total source area is 275.4677 km*km. To normalize the photon leakage out of each side of the BLIRB space to photons/source photon, it was necessary to divide the leakage for each side by the number of histories ran.

In addition to the extinction coefficients defined in section 1, AGGIE calculations were also run for extinction coefficients of 1.5, 3.0, 4.0, 7.5, and 15 1/km. Table 1 lists the photon leakage per source photon and the percent standard deviation (STD) for the leakage for each of the six sides of the BLIRB space when the incident zenith angle is 0.0°. Table 1 also lists the results obtained from the BLIRB code (Wells 1995). The AGGIE/BLIRB data ratio is also listed in table 1 for each case the BLIRB data were available. The AGGIE leakage data were always slightly greater then the BLIRB data for sides 1, 2, 3, and 4. The worst agreement in the two calculations occurred for cloud extinction coefficients of 0.2 and 10.0 1/km where the AGGIE data were 11 to 16 percent higher than the BLIRB data. The AGGIE/BLIRB ratio was the largest for side 6 where it varied from 0.861 to 1.13. The ratio for the total leakage from all sides of the BLIRB space was approximately 1.0 for extinction coefficient of 0.2, 0.8, 1.0, 2.0, and 5.0 1/km. The ratio was 1.121 for only an extinction coefficient of 10 1/km. The AGGIE results for side 5 when the zenith angle was 0.0° were only about 4 to 13 percent higher than the BLIRB results for extinction coefficients of 0.2, 0.8, 1.0, and 2.0 1/km. For extinction coefficients of 5.0 and 10.0 1/km, there were significant differences between the AGGIE and BLIRB results for side 5.

Table 1. Comparison of AGGIE and BLIRB data for photons leaking out of sides of cloud; zenith angle = 0°, scenario 1 (photons/source photon)

Side No.	Total Photon Leakage	% STD	BLIRB Data	AGGIE/ BLIRB
Extinction Coefficient = 0.2 1/km				
1	.55903−01	.42499+01	.0488	1.146
2	.56909−01	.38002+01	.0488	1.166
3	.55471−01	.54131+01	.0488	1.137
4	.56747−01	.43348+01	.0488	1.162
5	.66893+00	.59729+01	.6960	.961
6	.14170−01	.75449+01	.0162	.875
Total	.90813+00		.9074	1.001
Extinction Coefficient = 0.8				
1	.11076+00	.26988+01	.1021	1.085
2	.11069+00	.29925+01	.1021	1.084
3	.10753+00	.29118+01	.1021	1.053
4	.10873+00	.29637+01	.1021	1.065
5	.21900+00	.16724+01	.2366	.926
6	.48269−01	.48472+01	.0558	.865
Total	.70498+00		.7009	1.006
Extinction Coefficient = 1.0				
1	.11201+00	.33826+01	.1046	1.071
2	.11100+00	.34273+01	.1046	1.061
3	.10856+00	.18259+01	.1045	1.039
4	.11196+00	.24744+01	.1047	1.069
5	.15306+00	.19807+01	.1626	.941
6	.57503−01	.39422+01	.0668	.861
Total	.65409+00		.6478	1.009
Extinction Coefficient = 1.5				
1	.10522+00	.32186+01		
2	.10219+00	.54902+01		
3	.10296+00	.33623+01		
4	.10352+00	.41858+01		
5	.68591−01	.37113+01		
6	.74851−01	.34350+01		
Total	.55733+00			

Table 1. Comparison of AGGIE and BLIRB data for photons leaking out of sides of cloud; zenith angle = 0°, scenario 1 (photons/source photon) (continued)

Side No.	Total Photon Leakage	% STD	BLIRB Data	AGGIE/ BLIRB
Extinction Coefficient = 2.0 1/km				
1	.91517−01	.43542+01	.0889	1.029
2	.89192−01	.37031+01	.0888	1.004
3	.90522−01	.40370+01	.0888	1.019
4	.93694−01	.50604+01	.0889	1.054
5	.32357−01	.41074+01	.0286	1.131
6	.88670−01	.22474+01	.1024	.866
Total	.48595+00		.4864	.999
Extinction Coefficient = 3.0				
1	.70624−01	.53971+01		
2	.70740−01	.45990+01		
3	.71017−01	.21158+01		
4	.71729−01	.47957+01		
5	.77678−02	.52599+01		
6	.10408+00	.30044+01		
Total	.39596+00			
Extinction Coefficient = 4.0				
1	.54656−01	.75064+01		
2	.56464−01	.42029+01		
3	.54439−01	.51388+01		
4	.56269−01	.50931+01		
5	.18167−02	.15410+02		
6	.11781+00	.34534+01		
Total	.34145+00			
Extinction Coefficient = 5.0				
1	.46357−01	.60233+01	.0450	1.030
2	.46143−01	.51483+01	.0449	1.028
3	.47746−01	.45028+01	.0449	1.063
4	.49205−01	.48638+01	.0450	1.093
5	.46313−03	.19149+02	.0003	1.543
6	.12215+00	.23020+01	.1315	.929
Total	.31206+00		.3116	1.001

Table 1. Comparison of AGGIE and BLIRB data for photons leaking out of sides of cloud; zenith angle = 0°, scenario 1 (photons/source photon) (continued)

Side No.	Total Photon Leakage	% STD	BLIRB Data	AGGIE/ BLIRB
Extinction Coefficient = 7.5 1/km				
1	.32744−01	.60197+01		
2	.33072−01	.62388+01		
3	.31623−01	.59837+01		
4	.32282−01	.85730+01		
5	.17687−04	.66571+02		
6	.13213+00	.42250+01		
Total	.26187+00			
Extinction Coefficient = 10.0				
1	.25199−01	.74147+01	.0226	1.115
2	.25193−01	.95709+01	.0225	1.119
3	.23870−01	.11672+02	.0225	1.061
4	.25136−01	.68060+01	.0226	1.112
5	.56814−06	.11374+03	.00002	.0284
6	.13813+00	.45779+01	.1216	1.136
Total	.23753+00		.21182	1.121
Extinction Coefficient = 15.0				
1	.16584−01	.84401+01		
2	.17109−01	.12620+02		
3	.16733−01	.11463+02		
4	.17499−01	.78863+01		
5	.35455−09	.27452+03		
6	.14335+00	.23849+01		
Total	.21127+00			

Figure 3 shows a plot of the average photon leakage from sides 1, 2, 3, and 4 for the AGGIE and BLIRB calculations. Figure 3 also shows the AGGIE and BLIRB data for side 6 and for the total leakage from the BLIRB space. The BLIRB leakage data for side 6 as a function of the cloud extinction coefficient for coefficients less than 5.0 1/km are about 15 percent higher than the AGGIE leakage data. The AGGIE data for side 6 are approximately 7 percent higher than the BLIRB data when the cloud extinction coefficient is 5.0 1/km and

approximately 14 percent higher when the cloud extinction coefficient is 10.0 1/km.

Figure 4 shows a comparison between the AGGIE and BLIRB calculated leakage data for side 5 of the BLIRB space. The AGGIE calculated leakage for side 5 falls off approximately exponentially with increasing values of the cloud extinction coefficient. The BLIRB data also decreases exponentially with increasing extinction coefficient until a value of 5.0 1/km is reached, after which the rate of falloff with increasing extinction coefficient is reduced. The results shown in table 1 and figure 4 for the BLIRB calculations for extinction coefficients of 5 and 10 1/km are roundoff values because they are reported by Wells (1995) to only one significant digit. Except for these two data points, the BLIRB data for scenario 1 and a zenith angle of 0.0° are in fair agreement with the AGGIE data. The total leakage from the BLIRB space as given in figure 4 for both AGGIE and BLIRB are in excellent agreement, with the largest disagreement (approximately 12 percent) occurring for an extinction coefficient of 10.0 1/km.

Table 2 is a comparison between the AGGIE and BLIRB data for scenario 1 when the source zenith angle is 84.3°. The percent STD of the AGGIE results was always less than 13 percent except for side 1 when the extinction coefficients are 7.5, 10.0, and 15.0 1/km. For those cases, the percent STDs are 19.264, 25.651, and 27.041, respectively. The largest differences between the AGGIE and BLIRB results occur for side 1 when the extinction coefficient was 0.2, 0.8, 1.0, 2.0, 3.0, and 5.0 1/km and for sides 2 and 6 when the extinction coefficient was greater than 1.5 1/km.

Figure 5 shows plots of AGGIE and BLIRB data for photons exiting sides 1, 2, 3, and 4 and the total photon leakage for scenario 1 BLIRB space and a zenith angle of 84.3°. Figure 5 shows good agreement between the AGGIE and BLIRB calculations of photons leaking from sides 1, 3, and 4 and the total leakage when the extinction coefficient is 15 1/km or less. The AGGIE and BLIRB calculated leakages for side 2 shown in figure 5 are in good agreement for extinction coefficients of 2 1/km and less. The agreement between the AGGIE and BLIRB data is poor for extinction coefficients greater than 2 1/km, with the agreement getting worse as the extinction coefficient increases. Side 2 is opposite side 1 through which 90.924 percent of the incident photons enter the BLIRB space.

Figure 6 shows a comparison of the AGGIE and BLIRB calculated leakages for scenario 1 from sides 5 and 6 when the zenith angle is 84.3°. For extinction coefficients greater than 0.8 1/km, the BLIRB calculations underpredict the AGGIE calculations for side 6 with the amount of the underprediction increasing from about 10 percent for an extinction coefficient of 1.0 to a factor of 2.775 for an extinction coefficient of 10.0 1/km. The agreement the AGGIE and BLIRB calculations for side 5, as shown in figure 6, is always between 1 and 8 percent, with the BLIRB data being slightly higher than the AGGIE data as the extinction coefficient increases to 10.0 1/km.

The data in tables 1 and 2 and figures 5 and 6 point out that the biggest differences between the AGGIE and BLIRB calculations for scenario 1 occurs for side 5 when the zenith angle is 0.0° and for sides 2 and 6 when the zenith angle is 84.3°. These differences show up when the extinction coefficient is greater than 1.0 1/km.

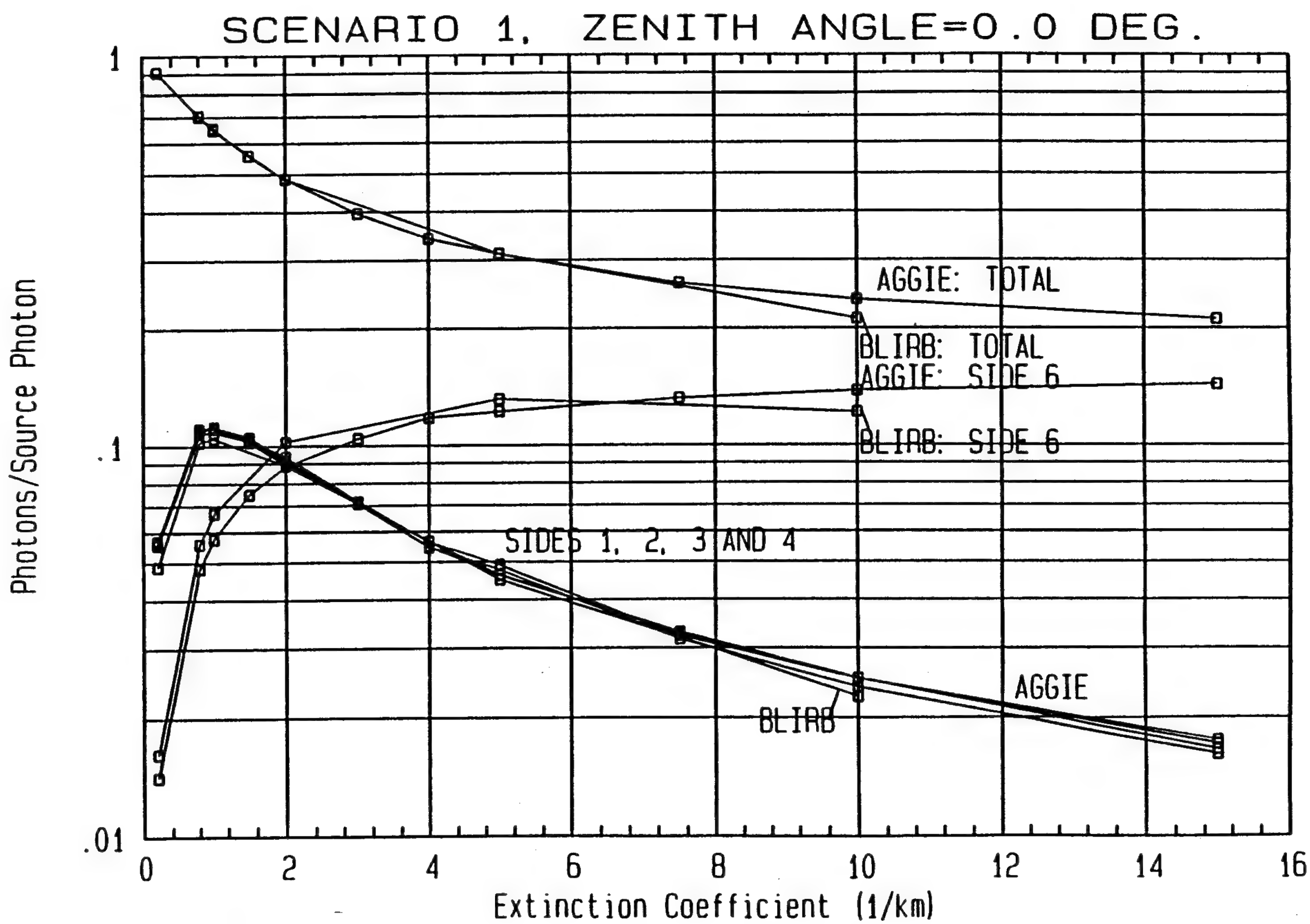

Figure 3. Fraction of incident photons exiting cloud sides and top.

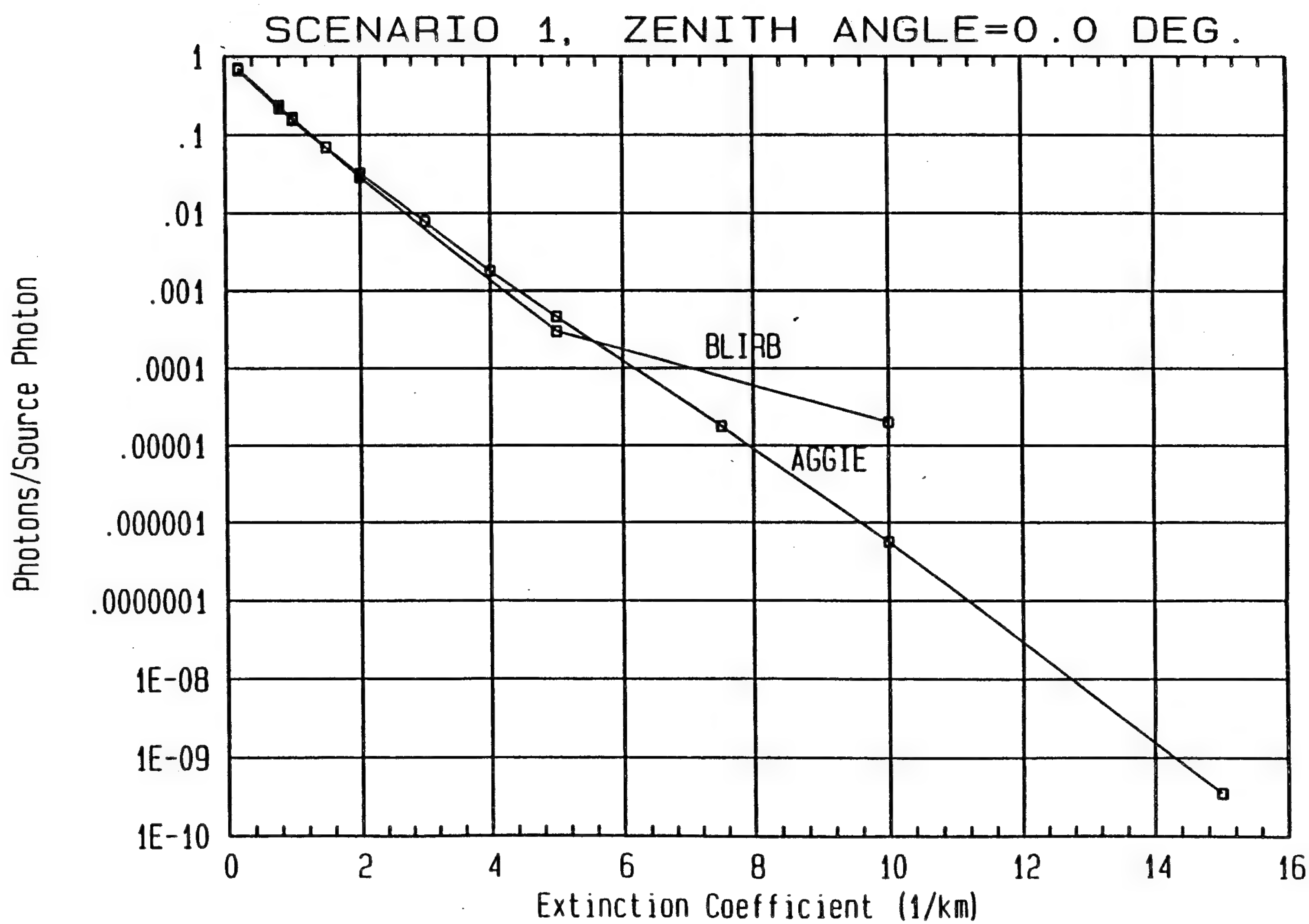

Figure 4. Fraction of incident photons exiting cloud bottom.

Table 2. Comparison of AGGIE and BLIRB data for photons leaking out of sides of cloud; zenith angle = 84.3°, scenario 1 (photons/source photon)

Side No.	Total Photon Leakage	% STD	BLIRB Data	AGGIE/ BLIRB
Extinction Coefficient = 0.2 1/km				
1	.12731−01	.71986+01	.0147	.866
2	.63404+00	.55274+00	.6511	.974
3	.51138−01	.40875+01	.0438	1.168
4	.52127−01	.31137+01	.0438	1.190
5	.12071+00	.36951+01	.1200	1.006
6	.44121−01	.43972+01	.0411	1.074
Total	.91486+00		.9145	1.000
Extinction Coefficient = 0.8				
1	.45429−01	.41764+01	.0525	.865
2	.23504+00	.22072+01	.2407	.976
3	.10148+00	.37519+01	.0957	1.061
4	.10114+00	.27896+01	.0967	1.046
5	.14140+00	.21425+01	.1408	1.004
6	.97991−01	.37484+01	.0949	1.033
Total	.72249+00		.7203	1.003
Extinction Coefficient = 1.0				
1	.54740−01	.59801+01	.0611	.896
2	.17288+00	.11465+01	.1828	.946
3	.10516+00	.26889+01	.0963	1.092
4	.10331+00	.18550+01	.0963	1.072
5	.13481+00	.31808+01	.1368	.985
6	.10529+00	.35288+01	.0952	1.106
Total	.67492+00		.6686	1.009
Extinction Coefficient = 1.5				
1	.69210−01	.54941+01		
2	.87913−01	.38264+01		
3	.98014−01	.31545+01		
4	.97354−01	.26566+01		
5	.11935+00	.38807+01		
6	.10578+00	.22495+01		
Total	.57762+00			

Table 2. Comparison of AGGIE and BLIRB data for photons leaking out of sides of cloud; zenith angle = 84.3°, scenario 1 (photons/source photon) (continued)

Side No.	Total Photon Leakage	% STD	BLIRB Data	AGGIE/ BLIRB
Extinction Coefficient = 2.0 1/km				
1	.80856−01	.36112+01	.0952	.849
2	.51760−01	.52182+01	.0446	1.160
3	.87462−01	.35792+01	.0835	1.047
4	.87037−01	.38750+01	.0836	1.041
5	.10339+00	.26860+01	.1069	.967
6	.99884−01	.31906+01	.0863	1.157
Total	.51039+00		.4974	1.026
Extinction Coefficient = 3.0 1/km				
1	.97804−01	.34399+01	.1129	.866
2	.22527−01	.74110+01	.0174	1.295
3	.67112−01	.74820+01	.0657	1.021
4	.67105−01	.60756+01	.0658	1.020
5	.77244−01	.37944+01	.0825	.936
6	.92935−01	.74288+01	.0693	1.341
Total	.42473+00		.4136	1.027
Extinction Coefficient = 4.0 1/km				
1	.10641+00	.40512+01		
2	.14195−01	.18512+02		
3	.53825−01	.31917+01		
4	.52254−01	.48131+01		
5	.61606−01	.58937+01		
6	.83702−01	.29009+01		
Total	.37199+00			
Extinction Coefficient = 5.0 1/km				
1	.11203+00	.46114+01	.1274	.879
2	.10930−01	.10560+02	.0045	2.492
3	.44831−01	.69343+01	.0438	1.024
4	.45208−01	.84845+01	.0439	1.030
5	.51012−01	.61268+01	.0555	.919
6	.75812−01	.45062+01	.0457	1.659
Total	.33983+00		.3208	1.059

Table 2. Comparison of AGGIE and BLIRB data for photons leaking out of sides of cloud; zenith angle = 84.3°, scenario 1 (photons/source photon) (continued)

Side No.	Total Photon Leakage	% STD	BLIRB Data	AGGIE/ BLIRB
Extinction Coefficient = 7.5 1/km				
1	.11999+00	.34680+01		
2	.65767−02	.19264+02		
3	.30856−01	.99357+01		
4	.31487−01	.70008+01		
5	.35031−01	.61388+01		
6	.64601−01	.65948+01		
Total	.28854+00			
Extinction Coefficient = 10.0				
1	.12426+00	.28861+01	.1217	1.021
2	.50265−02	.25851+02	.0003	16.755
3	.23995−01	.89840+01	.0223	1.076
4	.23677−01	.71205+01	.0224	1.057
5	.27810−01	.78706+01	.0301	.924
6	.60790−01	.75034+01	.0219	2.775
Total	.26555+00		.2187	1.214
Extinction Coefficient = 15.0				
1	.13245+00	.31622+01		
2	.30089−02	.27041+02		
3	.16811−01	.11496+02		
4	.16357−01	.13070+02		
5	.18695−01	.11382+02		
6	.54808−01	.83264+01		
Total	.24213+00			

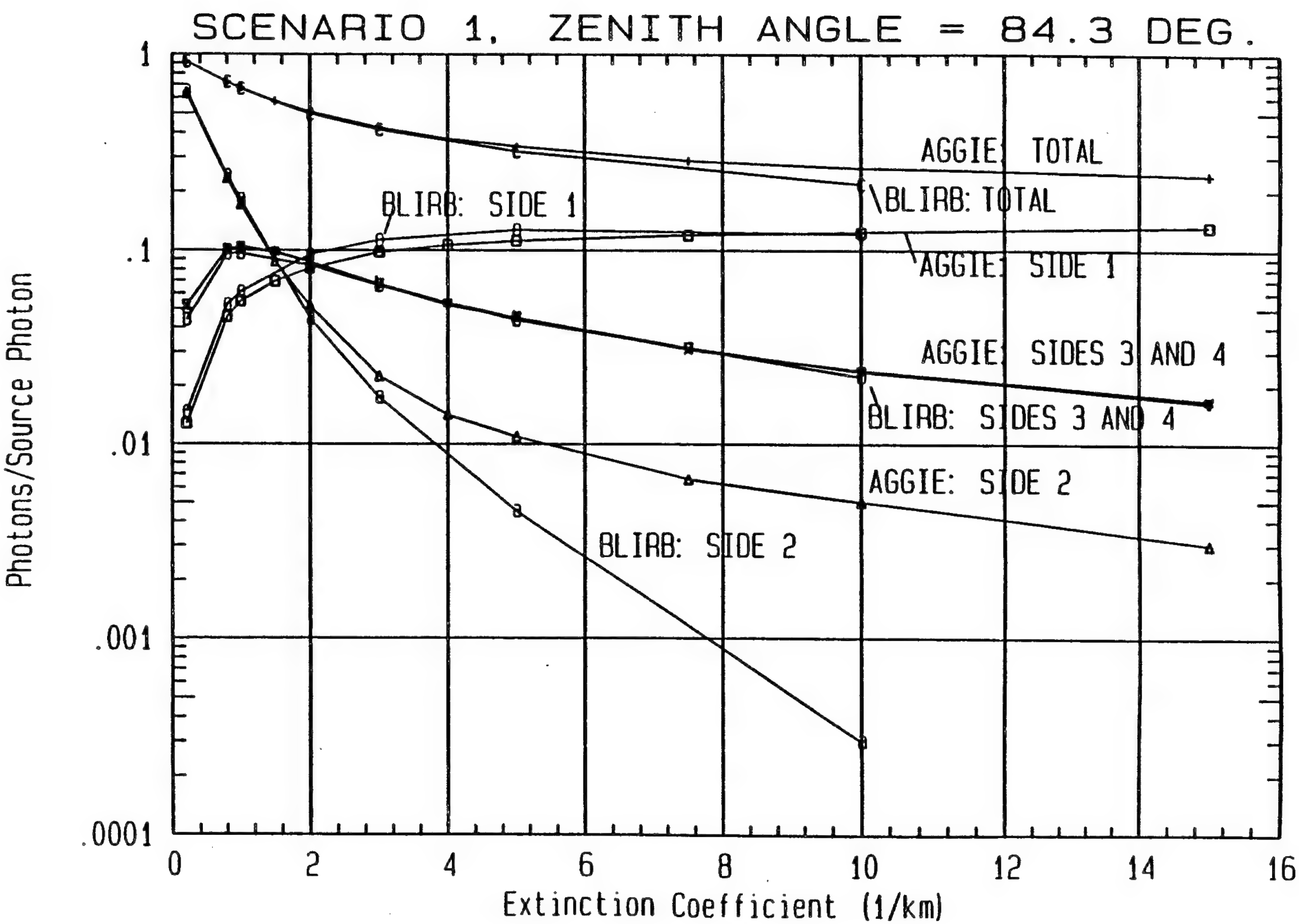

Figure 5. Fraction of incident photons exiting cloud sides.

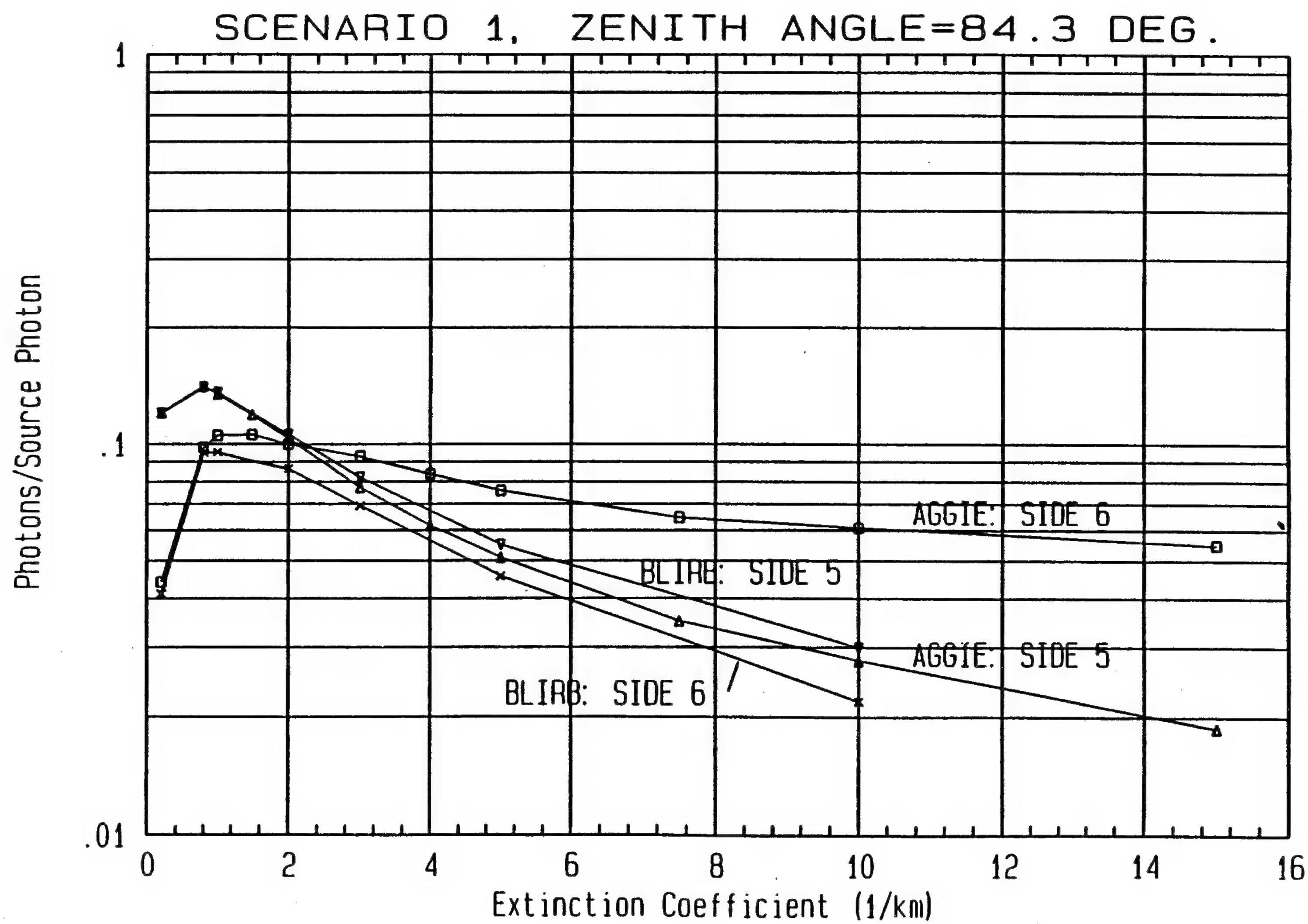

Figure 6. Fraction of incident photons exiting cloud top and bottom.

3. AGGIE Calculations for Scenario 2

Figure 2 shows the geometry used in the AGGIE calculations for scenario 2 when the zenith angles are 0.0° and 30°. Two different AGGIE runs were made for the 30° zenith angle case. In the first AGGIE run, the distance A was extended in the -X direction (figure 1). In the second run, the distance A was extended from X = +5 km to X = +7.88675 km and the source radiation was incident to both the top (side 6) and side 2 (the YZ plane at X = 5.0 km). The azimuthal angle for the radiation incident to the source area in the second AGGIE run was 180°. The bottom of the BLIRB space for all of the AGGIE runs was divided into 25 equal square areas and the leakage through each of these areas were calculated.

Tables 3, 4, and 5 list the leakage from sides 1, 2, 3, 4, 5, and 6 and the total leakage from all sides when the zenith angle is 0.0° and 30.0°, respectively. Table 4 lists the case where the source radiation is incident to the top and side 1 of the BLIRB space. Table 6 lists the case where the source radiation is incident to the top and side 2 of the BLIRB space.

Table 3 lists the AGGIE and BLIRB results for scenario 2 when the zenith angle is 0.0° and is a function of the cloud extinction coefficient for extinction coefficients of 1.0, 5.0, 10.0, and 25.0 1/km. Table 3 shows that the leakage through side 5 for all extinction coefficients is approximately 90 percent of the total leakage. When the zenith angle is 0.0°, 0.76 or 76 percent of the source photons will pass through side 5 of the BLIRB space without being attenuated or scattered by either of the two clouds contained within the BLIRB space. The leakage amount from side 5 exceeding 0.76 photons/source photon results from scattered photons. The AGGIE and BLIRB calculations for side 5 are in excellent agreement. The BLIRB leakage calculations for sides 1, 2, 3, 4, and 6 are all higher than the leakages given by AGGIE. The total leakage from all sides of the BLIRB space as given by the two different calculational methods are within 1 to 2.4 percent of each other.

Table 3. Comparison of AGGIE and BLIRB data for photons leaking out of sides of BLIRB space; zenith angle = 0.0°, scenario 2 (photons/source photon)

Side No.	Total Photon Leakage	BLIRB Data	AGGIE/ BLIRB
Extinction Coefficient = 1.0 1/km			
1	.15305−01	.0213	.7185
2	.19026−01	.0213	.8932
3	.15021−01	.0193	.7783
4	.15513−01	.0193	.8038
5	.89380+00	.8734	1.0234
6	.53964−02	.0072	.7495
Total	.96406+00	.9618	1.0023
Extinction Coefficient = 5.0			
1	.23273−01	.0270	.8619
2	.23749−01	.0230	1.0336
3	.18716−01	.0245	.7639
4	.18367−01	.0245	.7497
5	.78306+00	.7748	1.0107
6	.16034−01	.0211	.7599
Total	.88319+00	.8951	.9867
Extinction Coefficient = 10.0			
1	.17722−01	.0207	.8561
2	.15332−01	.0159	.9643
3	.13353−01	.0187	.7087
4	.13200−01	.0187	.7058
5	.76904+00	.7671	1.0025
6	.20081−01	.0254	.7906
Total	.84873+00	.8665	.9795
Extinction Coefficient = 25.0			
1	.10280−01	.0145	.7090
2	.73924−02	.0078	.9477
3	.75903−02	.0112	.6777
4	.75042−02	.0112	.6700
5	.75918+00	.7633	.9946
6	.23262−01	.0271	.8584
Total	.81514+00	.8351	.9761

Table 4. Comparison of AGGIE and BLIRB data for photons leaking out of sides of BLIRB space; zenith angle = 30.0°, scenario 2[a] (photons/source photon)

Side No.	Total Photon Leakage	BLIRB Data	AGGIE/ BLIRB
Extinction Coefficient = 1.0 1/km			
1	.68829−02	.0129	.5335
2	.34869+00	.3430	1.0166
3	.12651−01	.0171	.7398
4	.12665−01	.0171	.7406
5	.56435+00	.5703	.9896
6	.47679−02	.0072	.6622
Total	.95001+00	.9676	.9828
Extinction Coefficient = 5.0			
1	.19518−01	.0285	.6848
2	.31266+00	.3009	1.0391
3	.20362−01	.0286	.7119
4	.20542−01	.0286	.7183
5	.46562+00	.4720	.9865
6	.15032−01	.0222	.6771
Total	.85373+00	.8808	.9693
Extinction Coefficient = 10.0			
1	.22117−01	.0304	.7275
2	.29300+00	.2821	1.0386
3	.16540−01	.0222	.7450
4	.16727−01	.0222	.7535
5	.43144+00	.4414	.9768
6	.18259−01	.0256	.7132
Total	.79809+00	.8242	.9683
Extinction Coefficient = 25.0			
1	.21692−01	.0278	.7803
2	.27387+00	.2724	1.0054
3	.11472−01	.0158	.7261
4	.11329−01	.0158	.7170
5	.41375+00	.4206	.9837
6	.19694−01	.0302	.6521
Total	.75181+00	.7826	.9607

[a]Photons incident to +Z and -X sides of BLIRB space

Table 5. Comparison of AGGIE and BLIRB data for photons leaking out of sides of BLIRB space; zenith angle = 30.0°, scenario 2[a] (photons/source photon)

Side No.	Total Photon Leakage	BLIRB Data	AGGIE/ BLIRB
Extinction Coefficient = 1.0 1/km			
1	.27411−02	.0138	.19863
2	.32877+00	.3678	.89388
3	.38763−02	.0167	.23211
4	.38478−02	.0167	.23041
5	.44438+00	.5459	.81403
6	.15167−02	.0077	.18697
Total	.78514+00	.9686	.81059
Extinction Coefficient = 5.0			
1	.89416−02	.0282	.31708
2	.34988+00	.3442	1.01650
3	.13516−01	.0253	.53423
4	.13256−01	.0253	.52397
5	.44406+00	.4496	.98768
6	.11707−01	.0197	.59426
Total	.84136+00	.8923	.94291
Extinction Coefficient = 10.0			
1	.71942−02	.0272	.26449
2	.33480+00	.3298	1.01516
3	.10596−01	.0204	.51941
4	.10722−01	.0204	.52559
5	.43296+00	.4320	1.00222
6	.14977−01	.0231	.64835
Total	.81125+00	.8526	.95117
Extinction Coefficient = 25.0			
1	.51349−02	.0236	.21758
2	.32164+00	.3236	.99394
3	.69482−02	.0123	.56489
4	.70823−02	.0123	.57579
5	.42746+00	.4239	1.00840
6	.17246−01	.0229	.75310
Total	.78552+00	.8186	1.04305

[a]Photons incident to +Z and +X sides of BLIRB space

Table 6. Location of areas on cloud bottom for scenario 2

	X Coordinates (km)[a]				
Y coord (km)	0-1	1-2	2-3	3-4	4-5
0-1	AREA1	AREA2	AREA3	AREA4	AREA5
1-2	AREA6	AREA7	AREA8	AREA9	AREA10
2-3	AREA11	AREA12	AREA13	AREA14	AREA15
3-4	AREA16	AREA17	AREA18	AREA19	AREA20
4-5	AREA21	AREA22	AREA23	AREA24	AREA25
	X Coordinates (km)[b]				
Y coord (km)	0-1	1-2	2-3	3-4	4-5
0-1	AREA5	AREA4	AREA3	AREA2	AREA1
1-2	AREA10	AREA9	AREA8	AREA7	AREA6
2-3	AREA15	AREA14	AREA13	AREA12	AREA11
3-4	AREA20	AREA19	AREA18	AREA17	AREA16
4-5	AREA25	AREA24	AREA23	AREA22	AREA21

[a]Source zenith angle = 30° and source incident to +Z and −X sides of BLIRB space
[b]Source zenith angle = 30° and source incident to +Z and +X sides of BLIRB space

Figure 7 shows that the BLIRB data for sides 1, 2, 3, 4, and 6 are all greater in magnitude than the AGGIE results for those sides. Figure 8 shows the results of the two different calculations for the photon leakage from side 5 of the BLIRB space and the total leakage from all sides for a zenith angle of 0.0°. The AGGIE/BLIRB data ratio for side 5 is 1.0234, 1.0107, 1.0025, and .9946 for extinction coefficients of 1.0, 5.0, 10.0, and 25.0 1/km, respectively. Similarly, the AGGIE/BLIRB data ratio for the total leakage is 1.0023, 0.9867, 0.9795, and 0.9796 for cloud extinction coefficients of 1.0, 5.0, 10.0, and 25.0. As expected, the leakage through side 5 decreases with an increase in the cloud extinction coefficient. The leakage from side 6 increases with an increase in the cloud extinction coefficient. The leakage data for sides 1, 2, 3, and 4 increase with an increase in the extinction coefficient to a value of 5.0 1/km is reached, after that value the magnitude of the leakage decreases with increasing extinction coefficient.

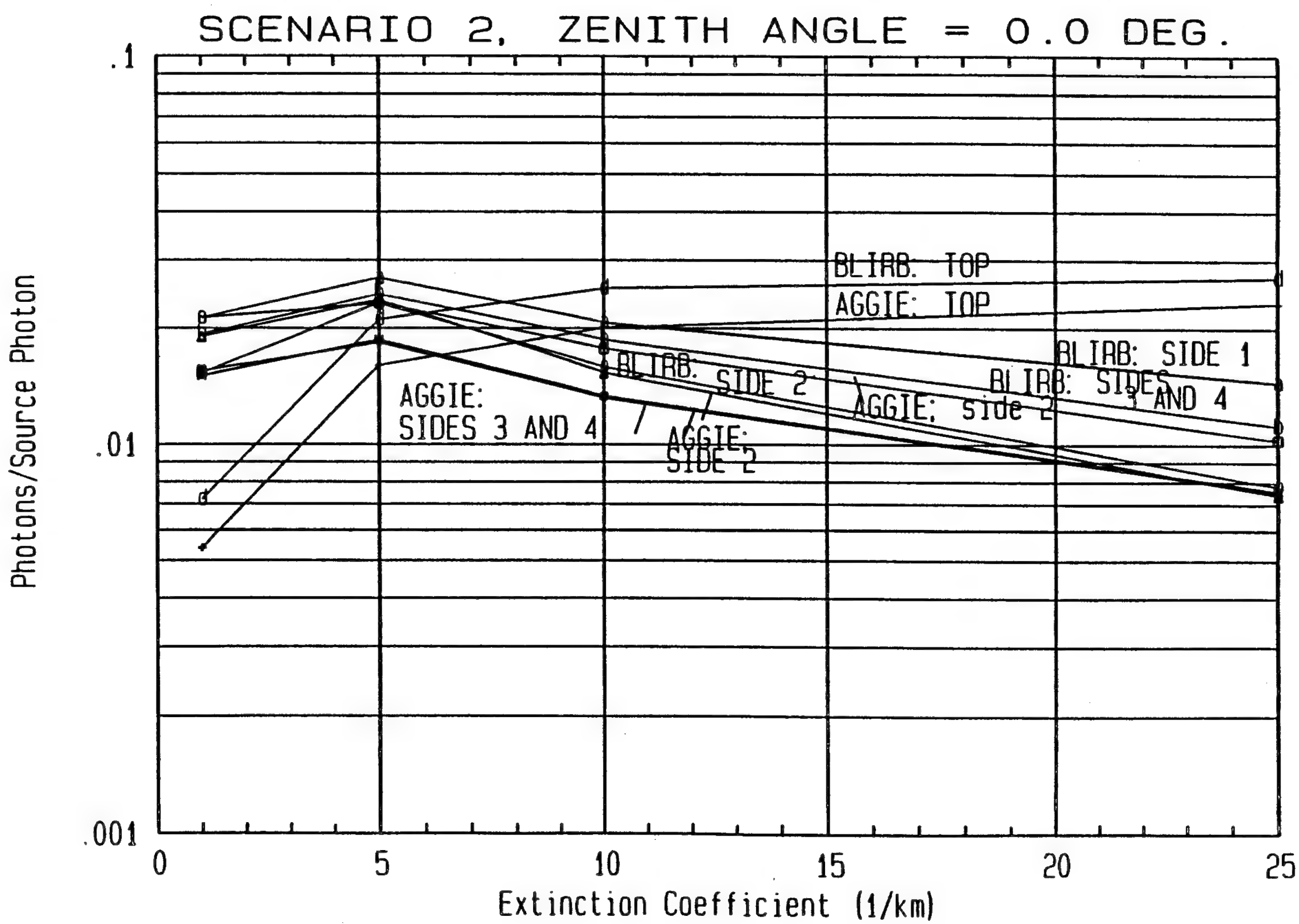

Figure 7. Fraction of incident photons exiting sides and top.

Table 3 shows that the AGGIE calculated leakage from sides 3 and 4 are approximately the same for each value of the extinction coefficient; the BLIRB data for each extinction coefficient are between 20 to 30 percent larger than the AGGIE data for those sides. The AGGIE data for side 1 is less than the BLIRB data for all extinction coefficients. The AGGIE and BLIRB data for side 2 are always within 11 percent of each other. The leakage out of side 6 increases with an increase in the magnitude of the extinction coefficient. Although the leakage from side 6 as given by BLIRB is always greater than that given by AGGIE, table 3 shows that the AGGIE/BLIRB data ratio is increasing from a value of .7495 to a value of .8584 as the extinction coefficient increases from a value of 1.0 to 25 1/km. The sum of the leakages from sides 1, 2, 3, 4, and 6 as given by BLIRB is about 20 to 28 percent larger than the sum given by AGGIE.

Figure 7 shows plots of the leakage from sides 1, 2, 3, 4, and 6 versus the extinction coefficient as given by AGGIE and BLIRB for scenario 2 for a zenith angle of 0.0°. Figure 8 shows plots of the leakage from side 5 and the total leakage versus the extinction when the zenith angle was 0.0°. Figure 7 shows that the maximum leakage from each of sides 1, 2, 3, and 4 occurs for an extinction coefficient of 5 1/km. In general, the BLIRB and AGGIE data for a given side have approximately the same shape versus the extinction coefficient with the BLIRB data being larger than the AGGIE data.

Figure 8 shows that the BLIRB data for both the total leakage and the leakage from side 5 is always larger than the AGGIE data. The differences between the AGGIE and BLIRB calculations for the total leakage and the leakage from side 5 are never greater than 2.5 percent of the AGGIE calculations.

Table 4 shows a comparison of AGGIE and BLIRB calculations of the photon leakage from the sides of the BLIRB space for scenario 2 when the zenith angle is 30° and the source photons are incident to the top and side 1 of the BLIRB space. Table 4 also shows that the two sides contributing between 91 and 96 percent of the total leakage are sides 2 and 5. The AGGIE/BLIRB data ratio for side 2 is 1.0054 to 1.0391, which shows that the AGGIE calculated values for side 2 is a maximum of approximately 4 percent higher than the BLIRB values for each extinction coefficient considered. The difference between the

AGGIE and BLIRB results for side 5 is never greater than approximately 2.5 percent. Similarly, the differences between the AGGIE and BLIRB data for the total leakage is always less than 4 percent. As expected, the leakage for sides 3 and 4 are approximately the same in the AGGIE calculations for each value of the extinction coefficient. The BLIRB data for sides 3 and 4 are about 35 to 40 percent higher than the AGGIE data for all values of the extinction coefficient. The BLIRB calculations the for the leakage from side 1 is 87 to 28 percent higher than the AGGIE data for side 1.

Figure 9 shows plots of the leakage from all six sides of the BLIRB space as a function of the extinction coefficient. The data in figure 9 are for the source incident to the top and side 1 of the BLIRB space for a zenith angle of 30.0°. Figure 9 shows there is good agreement between the AGGIE and BLIRB calculations for sides 2 and 5 and for the total leakage as a function of the cloud extinction coefficient. Figure 9 also shows that the AGGIE and BLIRB data versus the extinction for sides 3 and 4 are parallel, with the BLIRB data being about 35 to 40 percent higher than the AGGIE data. Similarly, the AGGIE and BLIRB data for side 1 are parallel, with the BLIRB data being higher. The BLIRB calculations for side 6 are also parallel with the AGGIE calculations for side 6 with the BLIRB data being about 50 percent higher than the AGGIE data. The contribution to the total leakage by sides 2 and 5 are 91 to 96 percent, respectively. Therefore, sides 1, 3, 4, and 6 contribute less than 9 percent to the total leakage.

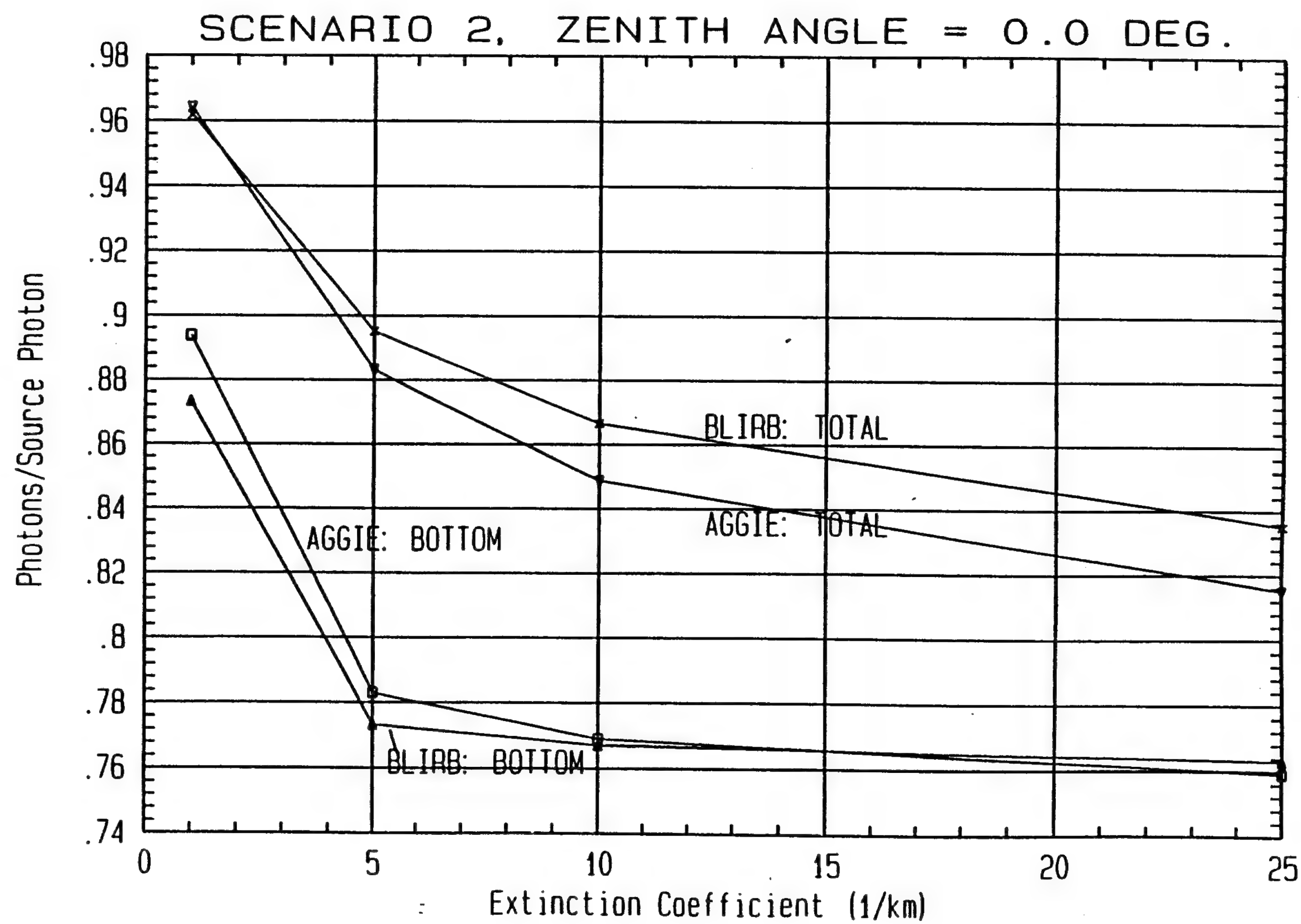

Figure 8. Fraction of incident photons exiting bottom.

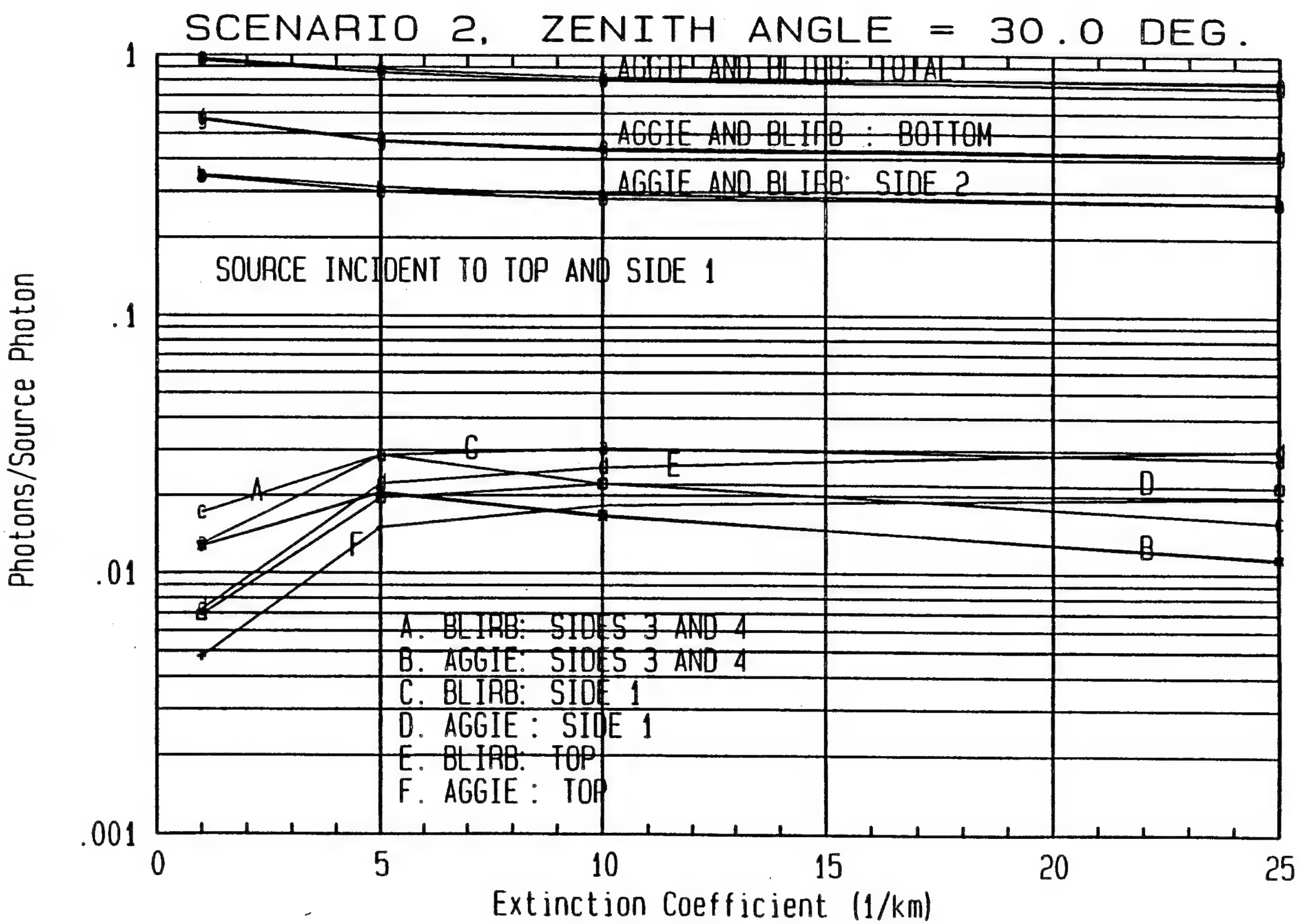

Figure 9. Fraction of incident photons exiting each side of BLIRB space.

Table 5 lists the results of the AGGIE and BLIRB calculations for photons leaking out of the sides of the BLIRB space for scenario 2 when the zenith angle is 30.0° and photons are incident to the top and side 2 of the BLIRB space. Sides 2 and 5 contribute between 86.5 to 95.36 percent of the total leakage with the percentage increasing with increasing extinction coefficient. The total leakage as given by the AGGIE calculations is 17 to 4 percent less than the total leakage given by BLIRB for extinction coefficients between 1.0 and 25.0 1/km. The leakage from side 6 increases with an increase in the extinction coefficient. The BLIRB data for side 6 is always higher than the AGGIE data for that side. The leakage from side 5 as given by the BLIRB and AGGIE data are in excellent agreement except for the case when the extinction coefficient is 1.0 1/km where the AGGIE value is about 81 percent of the BLIRB value. Plots of the AGGIE and BLIRB calculations for each side leakage and for the total leakage when the source radiation is incident to the top and side 2 of the BLIRB space when the zenith is 30° are shown in figure 10. As outlined above, sides 2 and 5 and the total leakage as given by the two different calculational methods are in good agreement. The agreement between the AGGIE and BLIRB calculations is not good for sides 1, 3, 4, and 6. For these sides, the BLIRB data are always greater than the AGGIE data.

The bottom of the BLIRB space was subdivided into 25 square areas with 1.0-km sides. Table 6 lists the X and Y coordinates for the 25 areas denoted as AREA1 through AREA25 for cases where the zenith angle is 0.0° or the zenith angle is 30.0° and the source radiation is incident to the top and side 1 of the BLIRB space, and the zenith angle is 30° and the source radiation is incident to the top and side 2 of the BLIRB space.

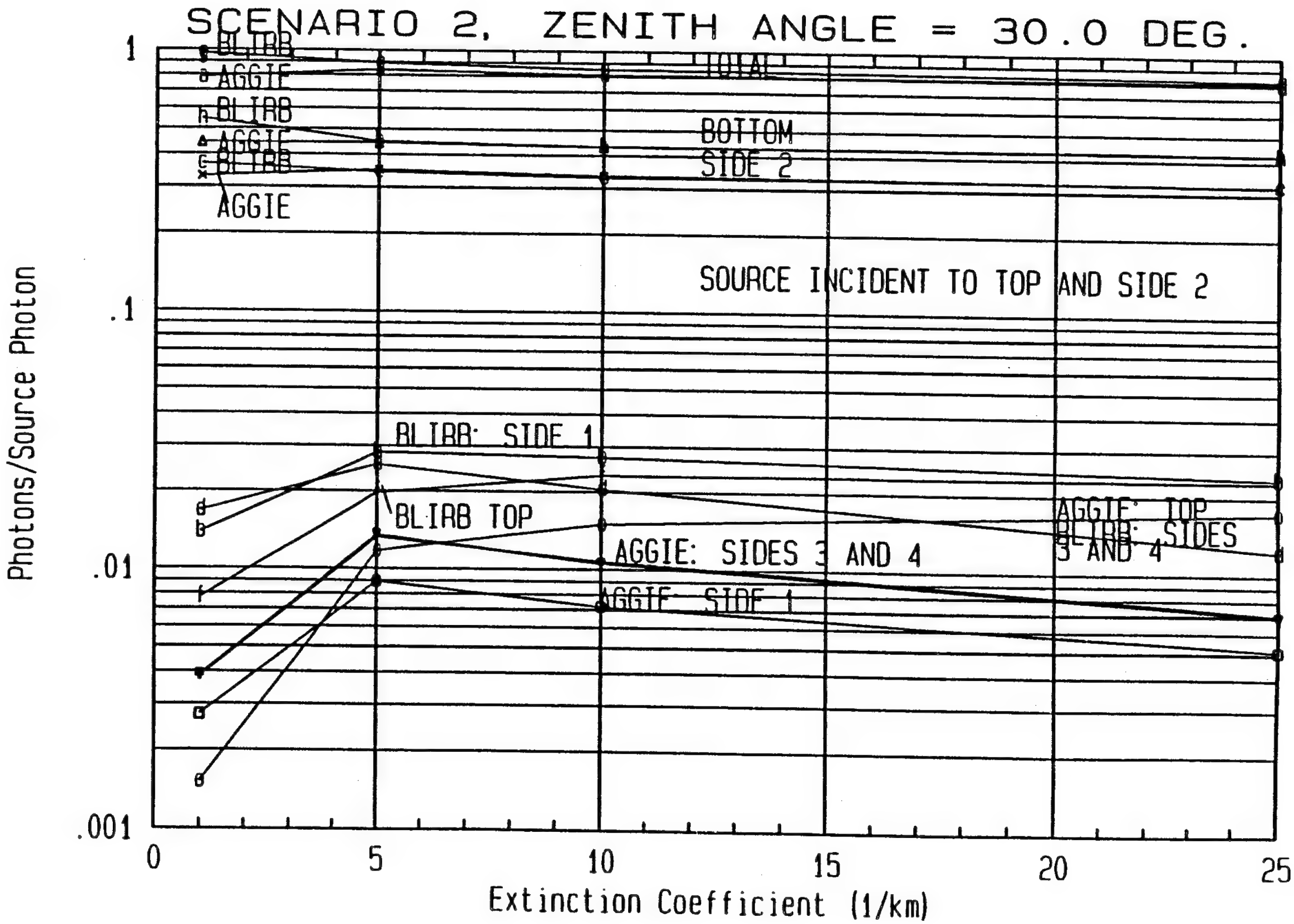

Figure 10. Fraction of incident photons exiting each side of BLIRB space.

Table 7 lists the leakage across AREA1 through AREA25 for the case where the zenith angle was 0.0°. Table 7 also lists the percent STDs of the leakage for each of the 25 areas on side 5 of the BLIRB space. Data are shown in table 7 for extinction coefficients of 1.0, 5.0, 10.0, and 25.0 1/km. For a zenith angle of 0.0°, the areas on side 5 of the BLIRB space which are shadowed by the enclosed clouds are AREA7, AREA8, AREA9, AREA12, AREA13, AREA14, AREA17, AREA18, and AREA19. These areas do not see any uncollided source radiation. AREA8, AREA13, and AREA18 have more scattered radiation leakage then any of the other unshadowed areas. The magnitude of the scattered leakage crossing AREA1 through AREA25 decreases with increasing extinction coefficient. The areas not shadowed by the two enclosed clouds should have 0.040 photons/source photon leaking through them that result from uncollided source radiation. Any excess leakage above 0.040 photons/source photon through the unshadowed areas results from photons scattered by the two clouds contained in the BLIRB space.

Table 8 lists the AGGIE calculations for AREA1 through AREA25 when the zenith angle is 30.0° and the source photons are incident to sides 1 and 6. Any of the 25 areas that are not shadowed by the two clouds should see a 0.025359 photons/source photon resulting from uncollided source photons. AREA1, AREA2, AREA3, AREA4, AREA5, AREA6, AREA11, AREA16, AREA21, AREA22, AREA23, AREA24, and AREA25 should see uncollided source photons. All other areas on the bottom of the BLIRB space should be partially or fully shadowed by the two clouds within the BLIRB space. For those areas showing leakage above the 0.025357 photons/source photon, the excess leakage above 0.025359 results from radiation scattered by the two clouds.

Table 9 lists the AGGIE calculated photon leakage per source photon through the 25 areas on side 5 of the BLIRB space when the zenith angle is 30° and the source photons are incident to sides 2 and 6. Any of the 25 areas that are not shadowed by the two clouds within the BLIRB space should see 0.025359 uncollided photons/source photon. Area numbers 1, 2, 3, 4, 5, 6, 11, 16, 21, 22, 23, 24, and 25 should see uncollided source radiation. All other areas on the bottom of the BLIRB space should be partially or fully shadowed by the two clouds within the BLIRB space. For those areas showing leakage

above 0.025357 photons/source photon, the excess over 0.025357 results from scattered radiation.

Table 10 lists the AGGIE and BLIRB calculated leakage data for each of the 25 areas on side 5 of the BLIRB space when the zenith angle is 0.0° and the cloud extinction is 5.0 and 10.0 1/km. The uncollided leakage for each of the 19 areas on side 5 of the BLIRB space that are not shadowed by the enclosed clouds is 0.040 photons/source photon. For an extinction coefficient of 5.0 1/km, a total uncollided leakage through side 5 of the BLIRB space of 0.75 photons/source photon would result, which is 96.8 percent of the total leakage of 0.7748 photons/source photon through side 5 as given by the BLIRB calculations. The uncollided leakage is 95.78 percent of the total leakage of 0.78306 photons/source photon as given by the AGGIE calculation for side 5 when the extinction coefficient is 5.0 1/km. Only about 3.3 to 4.2 percent of the photon leakage through side 5 of the BLIRB space is scattered radiation. The scattered photons/source photon leaking through each of the 19 areas on side 5 that include uncollided photons can be obtained by subtracting 0.040 from the data listed in tables 7 through 10 that are greater than 0.040. The photons that leak from the six shadowed areas result from scattered radiation. In general, the AGGIE calculations listed in table 10 were higher in magnitude then the BLIRB calculations for extinction coefficients of 5.0 and 10.0 1/km.

Table 7. Photon leakage from 25 equal areas on bottom of BLIRB space for scenario 2; source zenith angle = 0.0° (photons/source photon)

	Extinction Coefficient = 1.0 1/km			Extinction Coefficient = 5.0 1/km	
Area No.	Photon Leakage	% STD		Photon Leakage	% STD
1	.41748E−01	.46506E+01		.40215E−01	.37419E+01
2	.42679E−01	.51724E+01		.40903E−01	.31598E+01
3	.42450E−01	.38364E+01		.41311E−01	.31035E+01
4	.42935E−01	.36484E+01		.39951E−01	.41748E+01
5	.41575E−01	.41845E+01		.40683E−01	.60816E+01
6	.40313E−01	.10264E+02		.41088E−01	.89913E+01
7	.12638E−01	.48556E+01		.78207E−03	.15298E+02
8	.44301E−01	.29069E+01		.41684E−01	.30862E+01
9	.10354E−01	.51105E+01		.10097E−02	.14432E+02
10	.42031E−01	.38177E+01		.41014E−01	.45547E+01
11	.43784E−01	.22629E+01		.41604E−01	.31193E+01
12	.14005E−01	.45498E+01		.10247E−02	.82971E+01
13	.46399E−01	.31803E+01		.41636E−01	.31024E+01
14	.11424E−01	.48020E+01		.11647E−02	.10877E+02
15	.43723E−01	.23524E+01		.40759E−01	.51285E+01
16	.43470E−01	.32706E+01		.40844E−01	.35445E+01
17	.12663E−01	.50035E+01		.81706E−03	.15341E+02
18	.46147E−01	.37812E+01		.41313E−01	.26836E+01
19	.10338E−01	.51523E+01		.90830E−03	.12346E+02
20	.42674E−01	.23499E+01		.41057E−01	.29771E+01
21	.41685E−01	.15846E+01		.40526E−01	.35634E+01
22	.42460E−01	.41751E+01		.41357E−01	.30022E+01
23	.42704E−01	.47921E+01		.40596E−01	.46721E+01
24	.42595E−01	.33974E+01		.40147E−01	.59270E+01
25	.40647E−01	.43172E+01		.40663E−01	.37912E+01
sum =	.89380E+00		sum =	.78305E+00	

Table 7. Photon leakage from 25 equal areas on bottom of BLIRB space for scenario 2; source zenith angle = 0.0° (photons/source photon) (continued)

	Extinction Coefficient = 10.1 1/km			Extinction Coefficient = 25.0 1/km	
Area No.	Photon Leakage	% STD		Photon Leakage	% STD
1	.39392E−01	.44950E+01		.40452E−01	.51552E+01
2	.40081E−01	.36192E+01		.40207E−01	.54693E+01
3	.40696E−01	.42369E+01		.39258E−01	.27963E+01
4	.40949E−01	.38759E+01		.39683E−01	.20283E+01
5	.40931E−01	.32835E+01		.39855E−01	.49505E+01
6	.39475E−01	.13324E+02		.36000E−01	.15930E+02
7	.14657E−03	.20554E+02		.37992E−04	.73116E+02
8	.39677E−01	.35454E+01		.40623E−01	.20008E+01
9	.47065E−03	.18142E+02		.16291E−03	.26058E+02
10	.40527E−01	.39626E+01		.41009E−01	.56686E+01
11	.40808E−01	.34830E+01		.40843E−01	.33077E+01
12	.19419E−03	.32406E+02		.44913E−04	.41116E+02
13	.40958E−01	.44828E+01		.39756E−01	.33231E+01
14	.48497E−03	.16054E+02		.18827E−03	.42680E+02
15	.40466E−01	.49615E+01		.39411E−01	.36957E+01
16	.40696E−01	.44671E+01		.40858E−01	.34042E+01
17	.19838E−03	.30197E+02		.51717E−04	.72082E+02
18	.40317E−01	.43896E+01		.40839E−01	.36586E+01
19	.40093E−03	.13271E+02		.15358E−03	.32335E+02
20	.41042E−01	.39349E+01		.40043E−01	.57544E+01
21	.40316E−01	.36626E+01		.39418E−01	.31351E+01
22	.40605E−01	.37258E+01		.39614E−01	.38676E+01
23	.40260E−01	.36016E+01		.39818E−01	.32244E+01
24	.40418E−01	.38348E+01		.40646E−01	.47057E+01
25	.39531E−01	.40199E+01		.40207E−01	.32760E+01
sum =	.76904E+00		sum =	.75918E+00	

Table 8. Photon leakage from 25 equal areas on bottom of BLIRB space for scenario 2; source zenith angle = 30.0°[a] (photons/source photon)

	Extinction Coefficient = 1.0 1/km			Extinction Coefficient = 5.0 1/km	
Area No.	Photon Leakage	% STD		Photon Leakage	% STD
1	.25577E−01	.24181E+01		.26404E−01	.53669E+01
2	.26341E−01	.26995E+01		.26561E−01	.30102E+01
3	.27283E−01	.33895E+01		.26577E−01	.29312E+01
4	.26920E−01	.23746E+01		.26993E−01	.40303E+01
5	.27551E−01	.25320E+01		.26640E−01	.46430E+01
6	.25080E−01	.74067E+01		.26600E−01	.98592E+01
7	.11128E−01	.36996E+01		.59461E−02	.67300E+01
8	.10980E−01	.35489E+01		.25059E−02	.87038E+01
9	.20976E−01	.24799E+01		.12057E−01	.42725E+01
10	.18544E−01	.20877E+01		.87874E−02	.76928E+01
11	.26502E−01	.22295E+01		.26208E−01	.24613E+01
12	.26634E−01	.26495E+01		.21259E−01	.32577E+01
13	.11766E−01	.32803E+01		.28853E−02	.49230E+01
14	.21930E−01	.19532E+01		.12231E−01	.73729E+01
15	.19591E−01	.17490E+01		.95847E−02	.62787E+01
16	.26445E−01	.27742E+01		.26608E−01	.16573E+01
17	.25487E−01	.26664E+01		.20283E−01	.44366E+01
18	.11474E−01	.30894E+01		.28406E−02	.57869E+01
19	.20995E−01	.17622E+01		.11891E−01	.71069E+01
20	.18465E−01	.42122E+01		.91513E−02	.67293E+01
21	.26232E−01	.14671E+01		.26374E−01	.35879E+01
22	.26903E−01	.23931E+01		.26511E−01	.43541E+01
23	.27107E−01	.22821E+01		.27047E−01	.40848E+01
24	.27410E−01	.32053E+01		.26699E−01	.54257E+01
25	.27032E−01	.29903E+01		.26974E−01	.49909E+01
sum =	.56435E+00		sum =	.46562E+00	

[a]Source incident to +Z and −X sides of BLIRB space

Table 8. Photon leakage from 25 equal areas on bottom of BLIRB space for scenario 2; source zenith angle = 30.0°[a] (photons/source photon) (continued)

	Extinction Coefficient = 10.0 1/km		Extinction Coefficient = 25.0 1/km	
Area No.	Photon Leakage	% STD	Photon Leakage	% STD
1	.26111E−01	.33493E+01	.25571E−01	.54842E+01
2	.25482E−01	.39287E+01	.25911E−01	.43651E+01
3	.25667E−01	.46201E+01	.25996E−01	.66903E+01
4	.26081E−01	.42502E+01	.25390E−01	.44616E+01
5	.25717E−01	.55894E+01	.26050E−01	.58874E+01
6	.24350E−01	.69161E+01	.26600E−01	.18519E+02
7	.34620E−02	.60375E+01	.16525E−02	.21601E+02
8	.13564E−02	.94886E+01	.82037E−03	.20718E+02
9	.96740E−02	.45438E+01	.80265E−02	.94731E+01
10	.64973E−02	.51497E+01	.51461E−02	.90924E+01
11	.27121E−01	.55878E+01	.26303E−01	.45240E+01
12	.18737E−01	.39825E+01	.17421E−01	.78784E+01
13	.14951E−02	.77660E+01	.88277E−03	.23127E+02
14	.96237E−02	.59932E+01	.80485E−02	.11109E+02
15	.67586E−02	.79660E+01	.50853E−02	.13684E+02
16	.27027E−01	.20465E+01	.27125E−01	.53169E+01
17	.17915E−01	.43615E+01	.16329E−01	.58520E+01
18	.16357E−02	.12809E+02	.90764E−03	.14392E+02
19	.94212E−02	.83391E+01	.79016E−02	.69401E+01
20	.63228E−02	.96402E+01	.49250E−02	.16100E+02
21	.26591E−01	.29538E+01	.25046E−01	.47402E+01
22	.26437E−01	.46380E+01	.26591E−01	.48717E+01
23	.26024E−01	.41020E+01	.26095E−01	.70955E+01
24	.26164E−01	.35296E+01	.25953E−01	.67541E+01
25	.25774E−01	.59553E+01	.26003E−01	.61993E+01
sum =	.43144E+00	sum =	.41375E+00	

[a]Source incident to +Z and −X sides of BLIRB space

Table 9. Photon leakage from 25 equal areas on bottom of BLIRB space for scenario 2; source zenith angle = 30.0°[a] (photons/source photon)

	Extinction Coefficient = 1.0 1/km			Extinction Coefficient = 5.0 1/km	
Area No.	Photon Leakage	% STD		Photon Leakage	% STD
1	.25018E−01	.41196E+01		.26216E−01	.39050E+01
2	.25188E−01	.49432E+01		.25448E−01	.33244E+01
3	.25627E−01	.21244E+01		.25864E−01	.22588E+01
4	.25560E−01	.24650E+01		.25865E−01	.25824E+01
5	.26087E−01	.48808E+01		.26509E−01	.52574E+01
6	.25504E−01	.45708E+01		.25427E−01	.42519E+01
7	.26010E−01	.49914E+01		.25657E−01	.38816E+01
8	.76267E−02	.60699E+01		.75678E−02	.10452E+02
9	.14491E−02	.99600E+01		.10105E−02	.16025E+02
10	.11950E−02	.44430E+01		.79792E−03	.11600E+02
11	.26083E−01	.57731E+01		.25449E−01	.34397E+01
12	.26093E−01	.21659E+01		.26157E−01	.29519E+01
13	.79299E−02	.47261E+01		.81711E−02	.46192E+01
14	.16695E−02	.97946E+01		.13101E−02	.80274E+01
15	.15140E−02	.67353E+01		.10646E−02	.12652E+02
16	.25626E−01	.32933E+01		.25673E−01	.39208E+01
17	.26121E−01	.45001E+01		.26492E−01	.43860E+01
18	.77802E−02	.43745E+01		.76179E−02	.52294E+01
19	.14001E−02	.90618E+01		.98946E−03	.12613E+02
20	.12270E−02	.86774E+01		.84361E−03	.12862E+02
21	.25247E−01	.24506E+01		.25089E−01	.39563E+01
22	.26097E−01	.31170E+01		.26143E−01	.43494E+01
23	.25361E−01	.28341E+01		.25839E−01	.38146E+01
24	.26592E−01	.26366E+01		.26067E−01	.37476E+01
25	.26374E−01	.53708E+01		.26793E−01	.54298E+01
sum =	.44438E+00		sum =	.44406E+00	

[a]Source incident to +Z and +X sides of BLIRB space

Table 9. Photon leakage from 25 equal areas on bottom of BLIRB space for scenario 2; source zenith angle = 30.0°[a] (photons/source photon) (continued)

	Extinction Coefficient = 10.0 1/km			Extinction Coefficient = 25.0 1/km	
Area No.	Photon Leakage	% STD		Photon Leakage	% STD
1	.25439E−01	.32428E+01		.25347E−01	.36598E+01
2	.25751E−01	.44419E+01		.25872E−01	.44632E+01
3	.25900E−01	.55362E+01		.25963E−01	.55123E+01
4	.26231E−01	.23661E+01		.25272E−01	.34852E+01
5	.25581E−01	.39101E+01		.25072E−01	.49422E+01
6	.25740E−01	.32103E+01		.26069E−01	.32163E+01
7	.25987E−01	.42916E+01		.25897E−01	.46532E+01
8	.59094E−02	.66054E+01		.47849E−02	.90681E+01
9	.26904E−03	.19234E+02		.11409E−03	.40815E+02
10	.21071E−03	.28324E+02		.79095E−04	.42924E+02
11	.25784E−01	.34263E+01		.25693E−01	.37416E+01
12	.25766E−01	.37774E+01		.26095E−01	.31123E+01
13	.61321E−02	.14080E+02		.48499E−02	.89740E+01
14	.35011E−03	.17092E+02		.12245E−03	.32675E+02
15	.26819E−03	.12426E+02		.84511E−04	.40382E+02
16	.25712E−01	.31796E+01		.26209E−01	.27650E+01
17	.26497E−01	.41492E+01		.25736E−01	.45977E+01
18	.60381E−02	.61613E+01		.51088E−02	.90630E+01
19	.27504E−03	.19890E+02		.11070E−03	.46348E+02
20	.23162E−03	.24464E+02		.79820E−04	.37702E+02
21	.25423E−01	.33371E+01		.25213E−01	.57694E+01
22	.25865E−01	.53659E+01		.26182E−01	.56410E+01
23	.26157E−01	.26051E+01		.26163E−01	.52447E+01
24	.25545E−01	.42475E+01		.25675E−01	.25111E+01
25	.25895E−01	.37408E+01		.25667E−01	.36453E+01
sum =	.43296E+00		sum =	.42746E+00	

[a]Source incident to +Z and +X sides of BLIRB space

Table 10. Comparison of BLIRB and AGGIE surface leakage distributions for scenario 2; zenith angle = 0.0° (photons/source photon)

Extinction Coefficient = 5 1/km[a]

Y (km)	0-1	1-2	2-3	3-4	4-5	Data
0-1	.04020	.04014	.04018	.04099	.04055	BLIRB
	.04215	.04903	.04131	.03995	.04068	AGGIE
1-2	.04020	.00046	.04021	.00118	.04042	BLIRB
	.04109	.00078	.04168	.00101	.04101	AGGIE
2-3	.04024	.00045	.04030	.00090	.04020	BLIRB
	.04160	.00102	.04164	.00116	.04076	AGGIE
3-4	.04020	.00046	.04021	.00118	.04042	BLIRB
	.04084	.00082	.04131	.00091	.04106	AGGIE
4-5	.04020	.04014	.04018	.04099	.04094	BLIRB
	.04053	.04136	.04060	.04015	.04066	AGGIE
Total	.7748					BLIRB
Total	.78305					AGGIE

Extinction Coefficient = 10 1/km[a]

Y (km)	0-1	1-2	2-3	3-4	4-5	Data
0-1	.04011	.04018	.04014	.04042	.04077	BLIRB
	.03939	.04008	.04070	.04095	.04093	AGGIE
1-2	.04010	.00018	.04022	.00040	.04046	BLIRB
	.00395	.00015	.03968	.00047	.04053	AGGIE
2-3	.04015	.00018	.04031	.00044	.04018	BLIRB
	.04081	.00019	.04096	.00048	.04047	AGGIE
3-4	.04010	.00018	.04023	.00040	.04046	BLIRB
	.04070	.00020	.04032	.00040	.04104	AGGIE
4-5	.04011	.04018	.04014	.04058	.04077	BLIRB
	.04032	.04061	.04026	.04042	.03953	AGGIE
Total	.7671					BLIRB
Total	.76904					AGGIE

[a]X (km)

Table 11 lists comparisons between AGGIE and BLIRB calculated leakages through the 25 areas on side 5 of the BLIRB space for scenario 2 when the zenith angle is 30° and the extinction coefficient is 5.0 and 10.0 1/km. The data in table 11 are for photons incident to sides 1 and 6 of the BLIRB space. Areas 1, 2, 3, 4, 5, 6, 11, 16, 21, 22, 23, 24, and 25 see uncollided photons. Areas 7, 11, and 17 see 0.57735*0.025357 = 0.014641 uncollided source photons. Areas 8, 9, 10, 13, 14, 15, 18, 19, and 20 are completely shadowed by the two clouds in the BLIRB space. The amount that the AGGIE and BLIRB data in those areas that see uncollided leakage exceed 0.025359 is scattered photons. The 12 areas on side 5 that have leakages below 0.025359 photons/source photon see uncollided and scattered photons or only scattered photons, depending on if the area is partially shadowed. The total uncollided radiation leakage from side 5 of the BLIRB space is 0.37359 photons/source photon. The total leakage from side 5 when the extinction coefficient is 5.0 1/km is 0.4720 for the BLIRB calculation and 0.46562 for the AGGIE calculation. These total leakages result in scattered leakages of 0.09841 and 0.09203 photons/source photon for the BLIRB and AGGIE calculations, respectively. The BLIRB calculation gives about 6.48 percent more scattered leakage from side 5 than the AGGIE calculation when the extinction coefficient is 5.0 1/km.

Table 12 lists a comparison between the AGGIE and BLIRB calculations for the 25 areas on side 5 of the BLIRB space for scenario 2 when the zenith angle is 30.0° for extinction coefficients of 5.0 and 10.0 1/km. The data in table 11 are for photons incident to sides 2 and 6 of the BLIRB space for scenario 2. The uncollided photons passing through each of the areas on side 5 of the BLIRB space not shadowed by the two clouds within the BLIRB space is 0.025359 photons/source photon. Those areas with leakage less than 0.025359 are shadowed and their leakage may contain a contribution from uncollided source photons. The scattered photons leaking those areas that are not shadowed is the total leakage from the area minus 0.025359 photons/source photon. There are 16 areas containing contributions from both scattered and uncollided photons. There are three areas that are partially shadowed and see only .003923 uncollided photons/source photon and six areas that do not see any uncollided photons. When the extinction coefficient is 5.0 1/km, the total uncollided radiation leaking from side 5 of the BLIRB space is

.4175 photons/source photon. The total scattered photons leaking from side 5 is .1199 photons/source photon for the BLIRB calculation and .1144 photons/source photon for the AGGIE calculation. When the extinction coefficient is 10.0 1/km, the scattered photons leaking out of side 5 of the BLIRB space is 0.0321 photons/source photon for the BLIRB calculation and .0231 for the AGGIE calculation. In general, the AGGIE and BLIRB calculations of the total leakage from side 5 do not differ by more than 6.0 percent, except for the case where the zenith angle is 30°, the source radiation is incident to sides 2 and 6, and the extinction coefficient is 1.0 1/km. The AGGIE data is only 81 percent of the BLIRB data for side 5 for that case.

Table 11. Comparison of BLIRB and AGGIE surface leakage distributions for scenario 2; zenith angle = 30.0°[a] (photons/source photon)

Extinction Coefficient = 5 1/km[b]

Y (km)	0-1	1-2	2-3	3-4	4-5	Data
0-1	.02608	.02600	.02606	.02644	.02648	BLIRB
	.02640	.02656	.02658	.02699	.02664	AGGIE
1-2	.02609	.01611	.00134	.01597	.00483	BLIRB
	.02660	.00595	.00251	.01206	.00879	AGGIE
2-3	.02632	.01625	.00174	.01548	.00454	BLIRB
	.02621	.02126	.02885	.01223	.00958	AGGIE
3-4	.02609	.01611	.00134	.01597	.00483	BLIRB
	.02661	.02028	.00284	.01189	.00915	AGGIE
4-5	.02608	.02595	.02606	.02644	.02648	BLIRB
	.02637	.02651	.02705	.02670	.02697	AGGIE
Total	.4720					BLIRB
Total	.46562					AGGIE

Extinction Coefficient = 10 1/km[b]

Y (km)	0-1	1-2	2-3	3-4	4-5	Data
0-1	.02573	.02582	.02571	.02586	.02637	BLIRB
	.02611	.02548	.02567	.02608	.02572	AGGIE
1-2	.02583	.01384	.00048	.01359	.00183	BLIRB
	.02435	.00346	.00136	.00967	.00650	AGGIE
2-3	.02605	.01390	.00082	.01343	.00143	BLIRB
	.02712	.01874	.00150	.00962	.00676	AGGIE
3-4	.02583	.01385	.00048	.01359	.00183	BLIRB
	.02703	.01792	.00164	.00942	.00632	AGGIE
4-5	.02573	.02582	.02571	.02586	.02637	BLIRB
	.02659	.02644	.02602	.02616	.02577	AGGIE
Total	.4414					BLIRB
Total	.43144					AGGIE

[a]Source incident to +Z and -X sides of BLIRB space
[b]X (km)

Table 12. Comparison of BLIRB and AGGIE surface leakage distributions for scenario 2; zenith angle = 30.0°[a] (photons/source photon)

			Extinction Coefficient = 5 1/km[b]			
Y (km)	0-1	1-2	2-3	3-4	4-5	Data
0-1	.02573	.02600	.02579	.02647	.02615	BLIRB
	.02651	.02586	.02586	.02545	.02622	AGGIE
1-2	.00076	.00111	.00477	.02642	.02579	BLIRB
	.00080	.00101	.00757	.02566	.02543	AGGIE
2-3	.00089	.00099	.00477	.02603	.02555	BLIRB
	.00106	.00131	.00817	.02616	.02545	AGGIE
3-4	.00076	.00111	.00477	.02642	.02579	BLIRB
	.00084	.00099	.00762	.02649	.02567	AGGIE
4-5	.02573	.02600	.02233	.02579	.02647	BLIRB
	.02679	.02607	.02584	.02614	.02509	AGGIE
Total	.4496					BLIRB
Total	.44406					AGGIE

			Extinction Coefficient = 10 1/km[b]			
Y (km)	0-1	1-2	2-3	3-4	4-5	Data
0-1	.02558	.02572	.02562	.02606	.02613	BLIRB
	.02558	.02622	.02590	.02575	.02544	AGGIE
1-2	.00020	.00043	.00153	.02600	.02578	BLIRB
	.00021	.00027	.00591	.02599	.02574	AGGIE
2-3	.00021	.00032	.00155	.02594	.02555	BLIRB
	.00027	.00035	.00613	.02577	.02578	AGGIE
3-4	.00020	.00043	.00153	.02600	.02577	BLIRB
	.00023	.00028	.00604	.02650	.02571	AGGIE
4-5	.02557	.05772	.02563	.02605	.02613	BLIRB
	.02589	.02555	.02616	.02587	.02542	AGGIE
Total	.4320					BLIRB
Total	.43296					AGGIE

[a]Source incident to +Z and +X sides of BLIRB space
[b]X (km)

4. AGGIE Calculations for Scenario 3

The geometry for scenario 3 is similar to that shown in figure 1 for a zenith angle of 0.0° and 60.0°. The lengths of the X and Y sides of the BLIRB space are 50 km and the length of the Z side is 5.0 km. The source area, when the zenith angle is 0.0°, is 2500.0 km*km. When the zenith angle is 60°, the source area is 2933.0127 km*km. The value of the distance A in figure 1 for scenario 3 when the zenith angle is 60.0° is 8.660254 km. The fraction of the source photons emitted by the 2933.0127 km*km source area that will enter side 1 of the BLIRB space is 0.14763 when the zenith angle is 60.0°. The fraction of the source photons entering the top of the BLIRB space is 0.85237 when the zenith angle is 60°.

Table 13 lists comparisons of the AGGIE and BLIRB calculations of the photon leakage from the six sides of the BLIRB space for the case where the source zenith angle is 0.0°, the asymmetry parameter g = 0.75 for a Henyey-Greenstein Phase function, and the single scattering albedo is 0.9. The region outside of the BLIRB space is considered to be a vacuum. Leakage data in table 13 are given for extinction coefficients of 1.0, 5.0, 10.0, and 25.0 1/km. The side of the BLIRB space having the largest contribution to the total leakage is side 6 when the zenith angle is 0.0°. The importance of the side 6 contribution to the total leakage increases with increasing extinction coefficient.

Figure 11 shows plots of the leakage from sides 1, 2, 3, 4, and 6 and the total leakage from the BLIRB space for scenario 3 when the zenith angle is 0.0°, g = 0.75, and a single scattering albedo of 0.9 for both the AGGIE and the BLIRB calculations. Figure 11 shows fair agreement between the AGGIE and BLIRB calculations. Figure 12 shows a comparison between the AGGIE and BLIRB calculations of the leakage from side 5 of the BLIRB space. The curve for the BLIRB data for side 5 changes shape after an extinction coefficient of 5.0 1/km is reached. For extinction coefficients greater than 5.0 1/km, the BLIRB data grossly overpredicts the AGGIE results.

Table 13. Comparison of AGGIE and BLIRB data for photons leaking out of sides of cloud; zenith angle = 0.0°, g = .75 , scenario 3 (photons/source photon)

Side No.	Total Photon Leakage	% STD	BLIRB Data	AGGIE/ BLIRB
Extinction Coefficient = 1.0 1/km				
1	.15974−01	.48167+01	.0159	.99537
2	.15653−01	.57936+01	.0159	1.01578
3	.16277−01	.42557+01	.0159	.97684
4	.16419−01	.65726+01	.0159	.96839
5	.29487+00	.63029+01	.2987	1.01299
6	.12872+00	.11435+01	.1513	1.17560
Total	.48791+00		.5136	1.05265
Extinction Coefficient = 5.0				
1	.53884−02	.13440+02	.0059	.91324
2	.48507−02	.15904+02	.0059	.82215
3	.54933−02	.10520+02	.0059	.93106
4	.55203−02	.16486+02	.0059	.935646
5	.11250−02	.11074+02	.0025	.45000
6	.15092+00	.22154+01	.1748	.86340
Total	.17330+00		.2009	.86262
Extinction Coefficient = 10.0				
1	.25864−02	.13253+02	.0030	.86214
2	.27001−02	.15166+02	.0030	.90003
3	.27038−02	.18772+02	.0030	.90127
4	.24822−02	.19072+02	.0030	.82740
5	.93084−06	.41000+02	.0012	.77567-04
6	.15084+00	.12130+01	.1648	.91533
Total	.16131+00		.1780	.90623
Extinction Coefficient = 25.0				
1	.96263−03	.64191+02	.0011	.87509
2	.97489−03	.32822+02	.0011	.88623
3	.11890−02	.33058+02	.0011	1.08090
4	.10933−02	.54893+02	.0011	.99391
5	.19705−31	.31617+03	.0005	3.941-29
6	.15269+00	.30817+01	.1226	1.24540
Total	.15691+00		.1275	1.23050

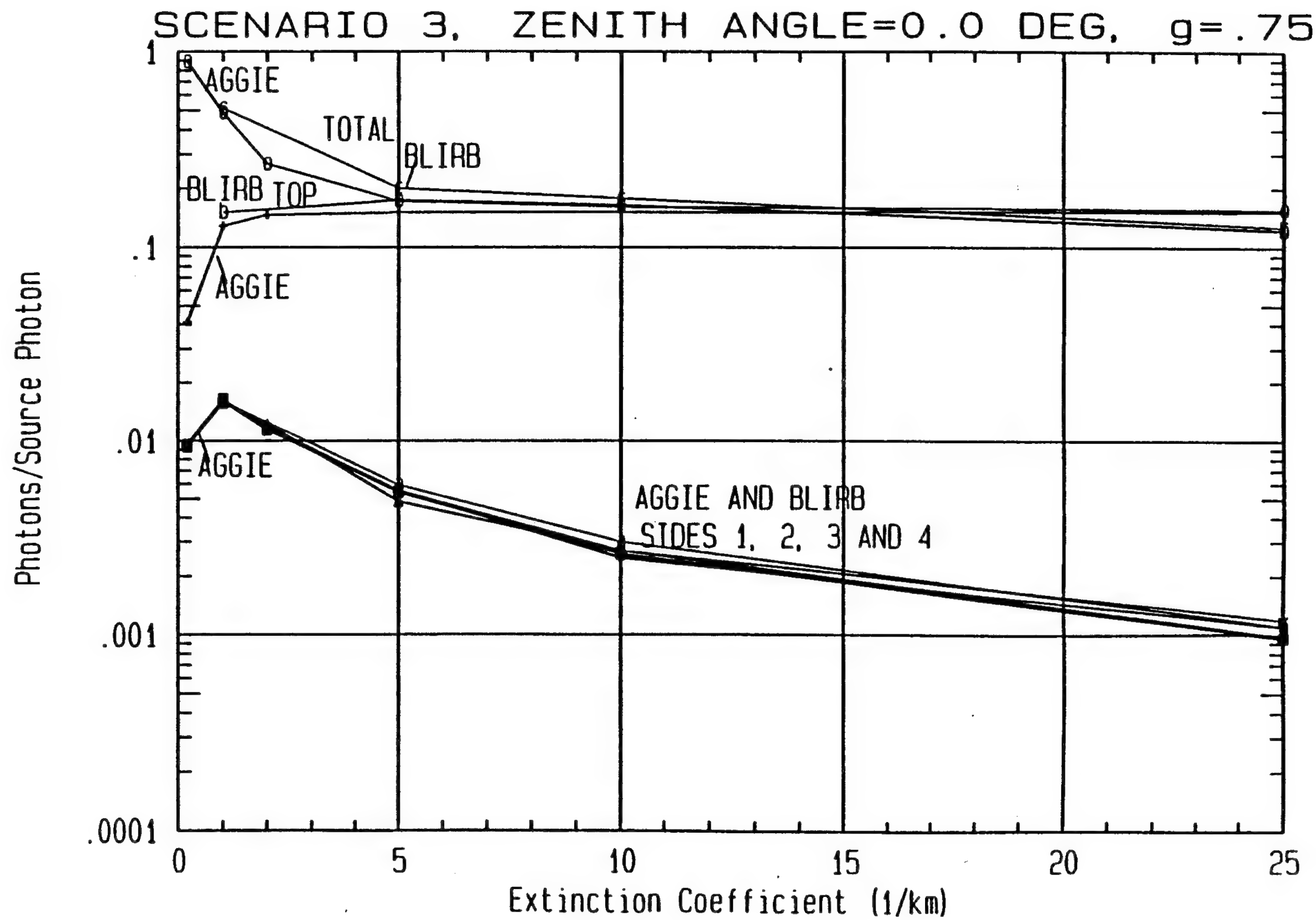

Figure 11. Fraction of incident photons exiting cloud sides and top.

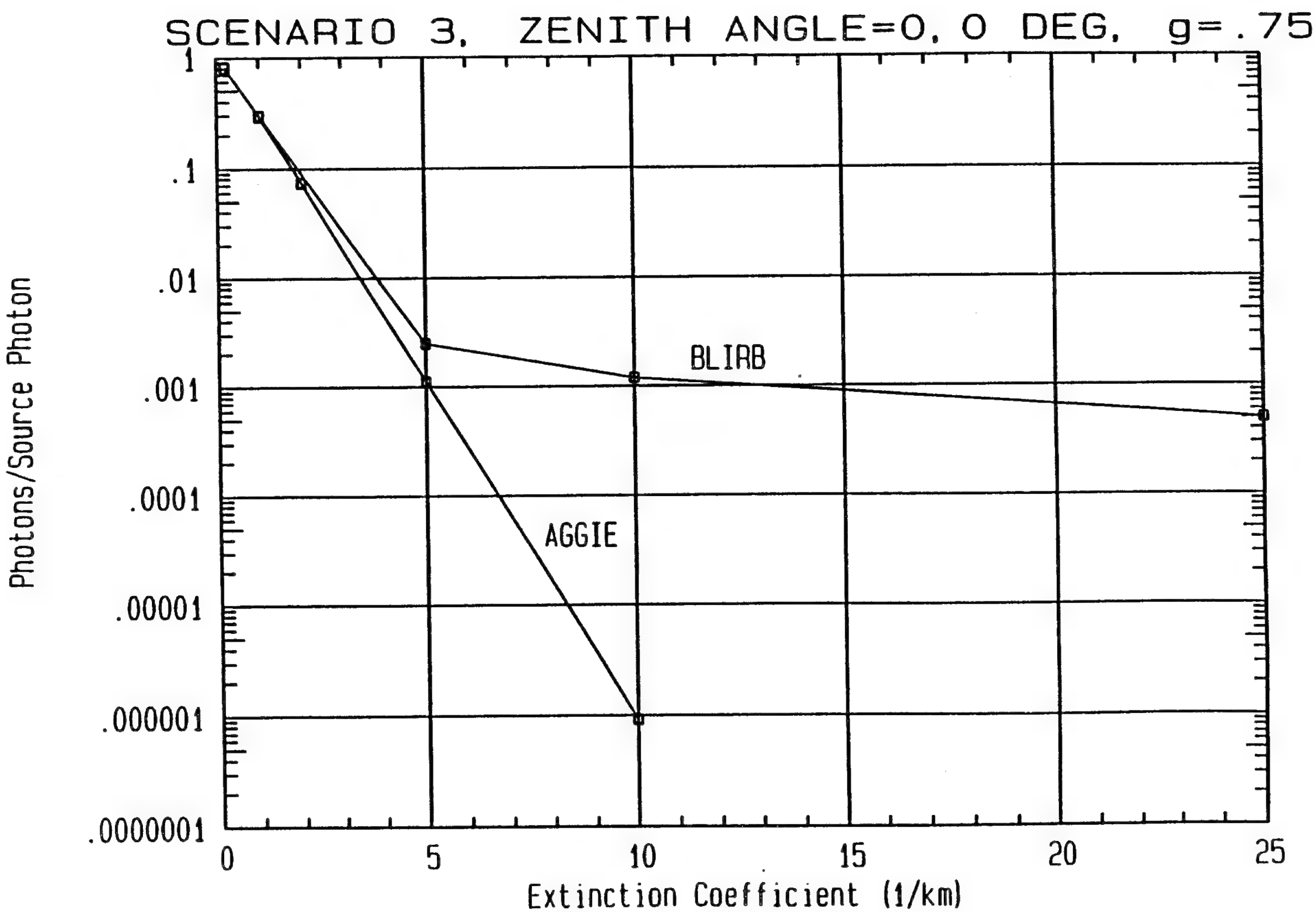

Figure 12. Fraction of incident photons exiting cloud bottom.

The percent STDs of the AGGIE calculated leakages given in table 12 for all sides of the BLIRB space except for side 6 are large (greater than 10 percent) for extinction coefficients of 5.0, 10.0, and 25.0 1/km. The leakages from sides 1 through 5 in table 12, when the extinction coefficient is 5.0, 10.0, and 25.0 1/km, are factors of 100 to 1000 smaller than the leakage for side 6. When the extinction coefficient is 1.0 1/km, the AGGIE and BLIRB calculated leakages are in good agreement, except for side 6 where the AGGIE leakage is 17.5 percent larger than the BLIRB leakage. The leakage through side 5 for extinction coefficients of 5.0, 10.0, and 25.0 1/km as given for the BLIRB calculations are always greater then the AGGIE calculations with the differences increasing with increasing values of the extinction coefficient. Except for side 5 when the extinction coefficient is 5.0, 10.0, and 25.0 1/km and side 6 when the extinction coefficient is 25.0 1/km, the BLIRB data do not differ from the AGGIE data by more than 18 percent.

Table 14 lists a comparison between the AGGIE and BLIRB data for the photon leakage from each of the sides of the BLIRB space for scenario 3 when the zenith angle is 0.0°, the asymmetry parameter g = 0.0, and the single scattering albedo is 0.9. The largest contributor to the total leakage is the leakage from side 6. The fraction of the total leakage contributed by side 6 is 0.76389, 0.97195, 0.98601, and 0.9959 for extinction coefficients of 1.0, 5.0, 10.0, and 25.0 1/km, respectively. The leakage from side 5 as given by both calculational methods are approximately the same for an extinction coefficient of 1.0 1/km, but the AGGIE data fall off at a much faster rate with increasing extinction coefficient than does the BLIRB data. The BLIRB data for sides 1, 2, 3, and 4 are always higher than the AGGIE data for those sides. The total leakage versus extinction coefficient as given by BLIRB and AGGIE are in good agreement with differences of less than 8 percent except for an extinction coefficient of 25.0 1/km where the BLIRB result for the total leakage is only 44.7 percent of the AGGIE calculated value.

Figure 13 shows plots of the fraction of the incident photons that leak out of sides 1, 2, 3, 4, and 6 and the total leakage when the zenith angle is 0.0° and g = 0.0 (isotropic scattering). The AGGIE and BLIRB results are in good agreement for side 6 and the total leakage from all sides of the BLIRB space. The AGGIE calculated leakage data for sides 1, 2, 3, and 4 are approximately equal for each value of the extinction coefficient. The AGGIE results for sides 1, 2, 3, and 4 are always less than the BLIRB data for those sides.

Table 14. Comparison of AGGIE and BLIRB data for photons leaking out of sides of cloud; zenith angle = 0.0°, g = 0.0, scenario 3[a] (photons/source photon)

Side No.	Total Photon Leakage	% STD	BLIRB Data	AGGIE/ BLIRB
Extinction Coefficient = 1.0 1/km				
1	.13245−01	.87360+01	.0158	.83829
2	.12455−01	.60970+01	.0158	.78829
3	.12605−01	.52799+01	.0158	.79778
4	.13352−01	.71916+01	.0158	.84506
5	.70318−01	.14895+01	.0691	1.01763
6	.39442+00	.89062+01	.4175	.81192
Total	.51633+00		.5498	.93912
Extinction Coefficient = 5.0				
1	.32358−02	.12767+02	.0044	.73541
2	.26612−02	.20804+02	.0044	.60482
3	.27970−02	.17856+02	.0044	.63568
4	.31619−02	.17868+02	.0044	.71861
5	.12530−05	.10083+03	.0018	.00007
6	.41081+00	.82186+00	.4212	.97533
Total	.42267+00		.4406	.95931
Extinction Coefficient = 10.0				
1	.14982−02	.25805+02	.0024	.62425
2	.14104−02	.26539+02	.0024	.59767
3	.15250−02	.40419+02	.0024	.63542
4	.14094−02	.24570+02	.0024	.68725
5	.10883−14	.30046+03	.0010	1.0883-12
6	.41158+00	.68780+00	.3791	1.08570
Total	.41742+00		.3897	1.07113
Extinction Coefficient = 25.0				
1	.33987−03	.72859+02	.0010	.33987
2	.44334−03	.57387+02	.0010	.44337
3	.51594−03	.52879+02	.0010	.51594
4	.41960−03	.72664+02	.0010	.41950
5	.36236−48	.30551+03	.0004	.9059-46
6	.41651+00	.13066+01	.2268	1.83646
Total	.41823+00		.2312	1.80895

[a]Isotropic scattering

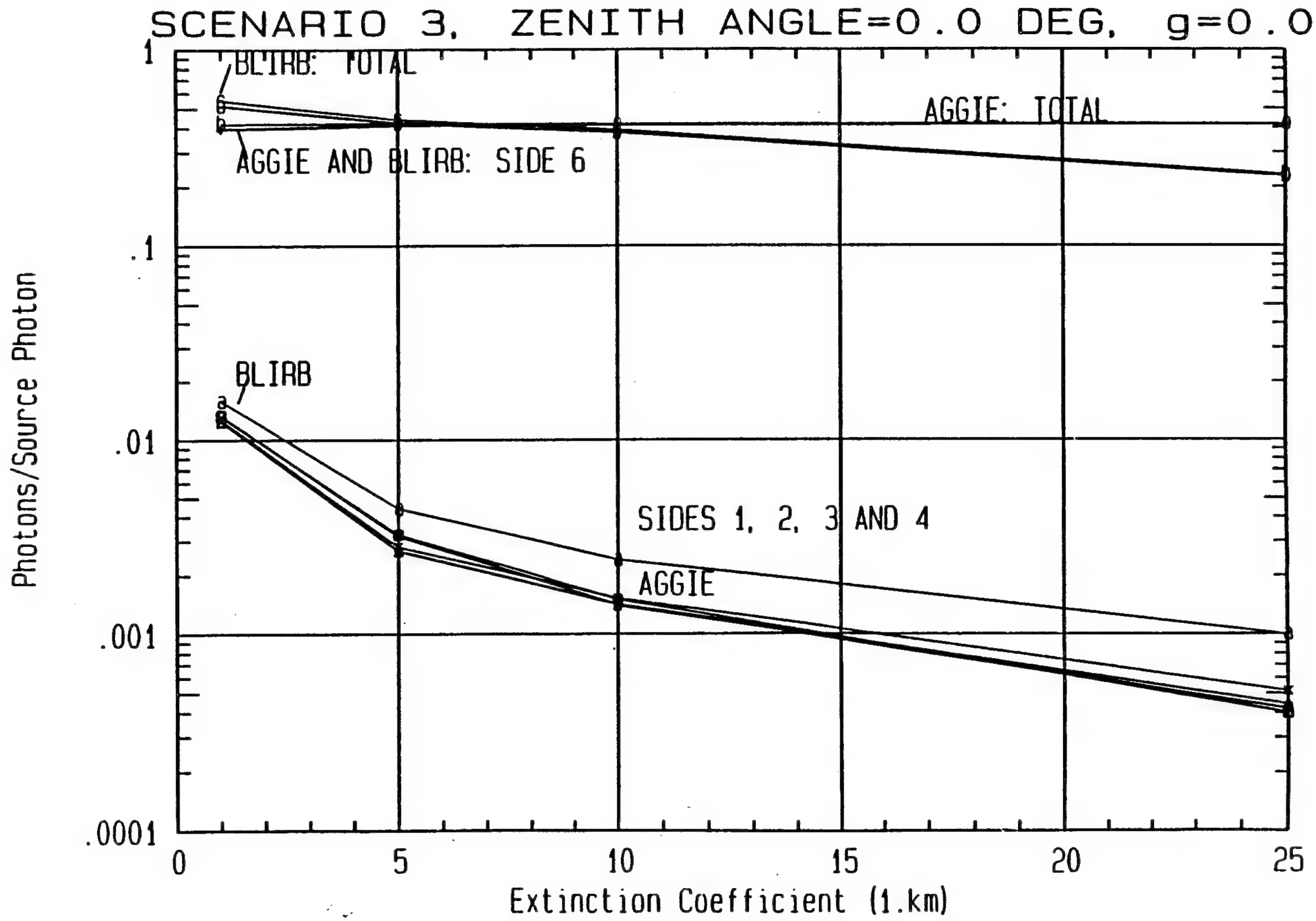

Figure 13. Fraction of incident photons exiting cloud sides and top.

Figure 14 shows a plot of the leakage data for side 5 as given by AGGIE and BLIRB for a zenith angle of 0.0° and g = 0.0. Except for the data at an extinction coefficient of 0.1 1/km, there is no agreement between the two calculations for side 5 as a function of the cloud extinction coefficient.

Table 15 lists a comparison of the AGGIE and BLIRB results for scenario 3 for a zenith angle of 60°, asymmetry parameter g = 0.75, and a single scattering albedo of 0.0. The largest contribution to the total leakage, as given by the AGGIE calculations, is the leakage from side 6. The percent of the total leakage contributed by side 6 for extinction coefficients of 1.0, 5.0, 10.0, and 25.0 1/km is 43.34, 79.06, 84.17, and 87.17, respectively. For a zenith angle of 60° and where part of the source photons enter the BLIRB space, side 1 acts as a reflection surface with the leakage increasing slightly with an increase in the cloud extinction coefficient. The BLIRB data for side 1 decreases with increasing extinction coefficient. The AGGIE total leakage data are in good agreement with the BLIRB data for extinction coefficients of 1.0 and 5.0 1/km. For extinction coefficients of 10.0 and 25.0 1/km, the AGGIE results are factors of 1.27 and 2.83 greater than the BLIRB results.

Figure 15 shows plots of the leakage versus extinction coefficient for sides 1, 2, 3, 4, and 6 and the total leakage for a zenith angle of 0.0° as given by the AGGIE and BLIRB calculations. Figure 16 shows plots of the leakage from side 5. The data in figures 15 and 16 are for the case where g = 0.75. Figures 15 and 16 show that the BLIRB data for all of the sides are in fair agreement with the AGGIE data for extinction coefficients of 1.0 and 5.0 1/km, except side 1. The agreement between the AGGIE and BLIRB data for sides 3 and 4 is fair for all extinction coefficients.

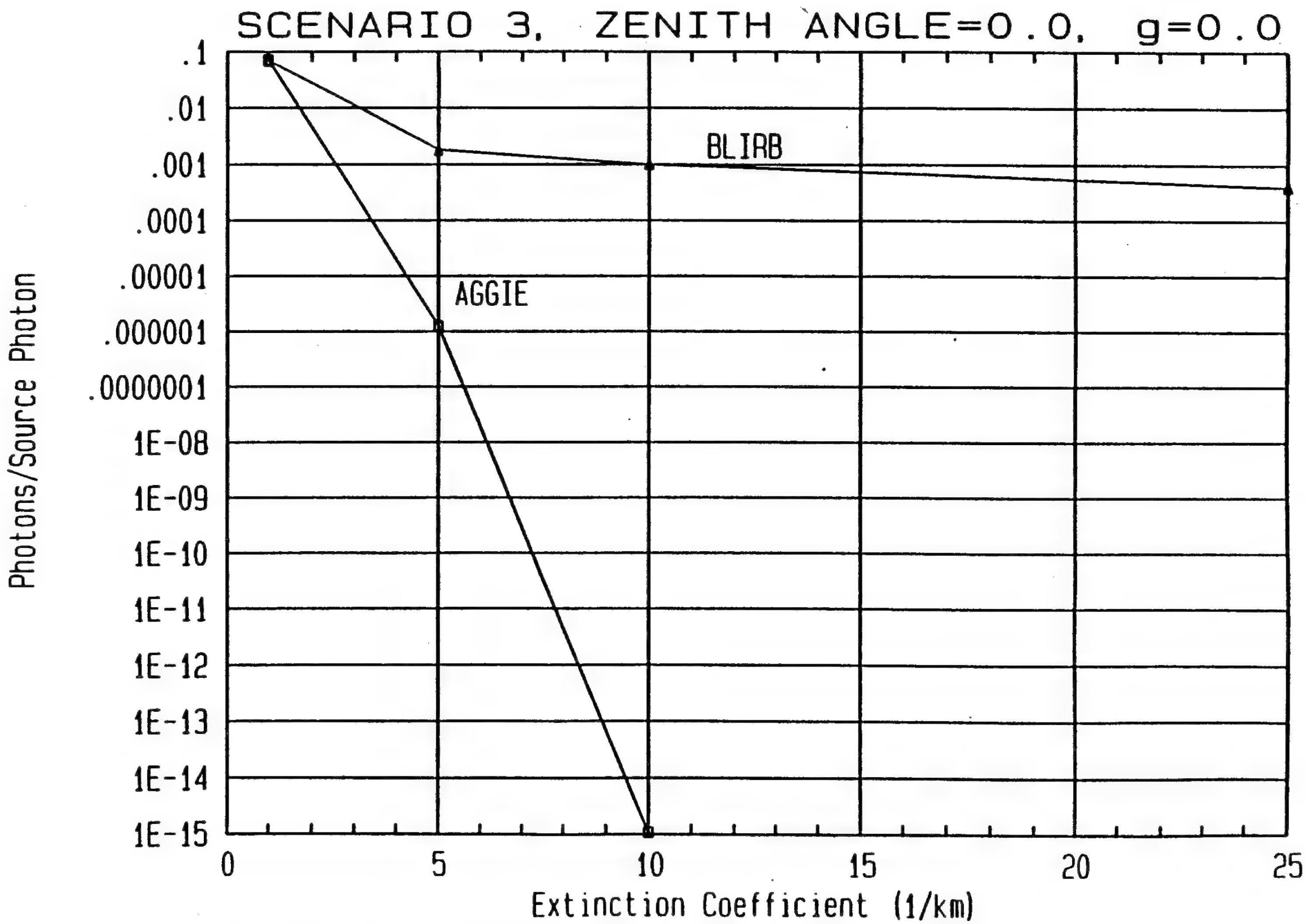

Figure 14. Fraction of incident photons exiting cloud bottom.

Table 15. Comparison of AGGIE and BLIRB data for photons leaking out of sides of cloud; zenith angle = 60°, g = 0.75, scenario 3 (photons/source photon)

Side No.	Total Photon Leakage	% STD	BLIRB Data	AGGIE/ BLIRB
Extinction Coefficient = 1.0 1/km				
1	.15874−01	.60770+01	.0177	.89683
2	.51578−01	.32845+01	.0509	1.01332
3	.15594−01	.80937+01	.0146	1.06808
4	.15607−01	.73928+01	.0146	1.06897
5	.18177+00	.15656+01	.1857	.97884
6	.21448+00	.14972+01	.2371	.90459
Total	.49490+00		.5206	.95063
Extinction Coefficient = 5.0				
1	.25542−01	.75779+01	.0119	2.14639
2	.11480−01	.14448+02	.0143	.80279
3	.45256−02	.15141+02	.0047	.96289
4	.40821−02	.14478+02	.0047	.86685
5	.15257−01	.15170+02	.0154	.99065
6	.22991+00	.21208+01	.2237	1.02776
Total	.29080+00		.2747	1.05861
Extinction Coefficient = 10.0				
1	.25833−01	.41175+01	.0037	6.98189
2	.56791−02	.11779+02	.0088	.64535
3	.20459−02	.20108+02	.0023	.88952
4	.24278−02	.23685+02	.0023	1.05557
5	.76635−02	.10855+02	.0046	1.66598
6	.23208+00	.25965+01	.1951	1.18954
Total	.27573+00		.2168	1.27182
Extinction Coefficient = 25.0				
1	.27164−01	.53650+01	.0005	54.32800
2	.23621−02	.22233+02	.0052	.45423
3	.78085−03	.32668+02	.0006	1.30133
4	.99818−03	.29026+02	.0006	1.66350
5	.28423−02	.16255+02	.0007	4.06043
6	.23209+00	.17825+01	.0865	2.68312
Total	.26625+00		.0941	2.82933

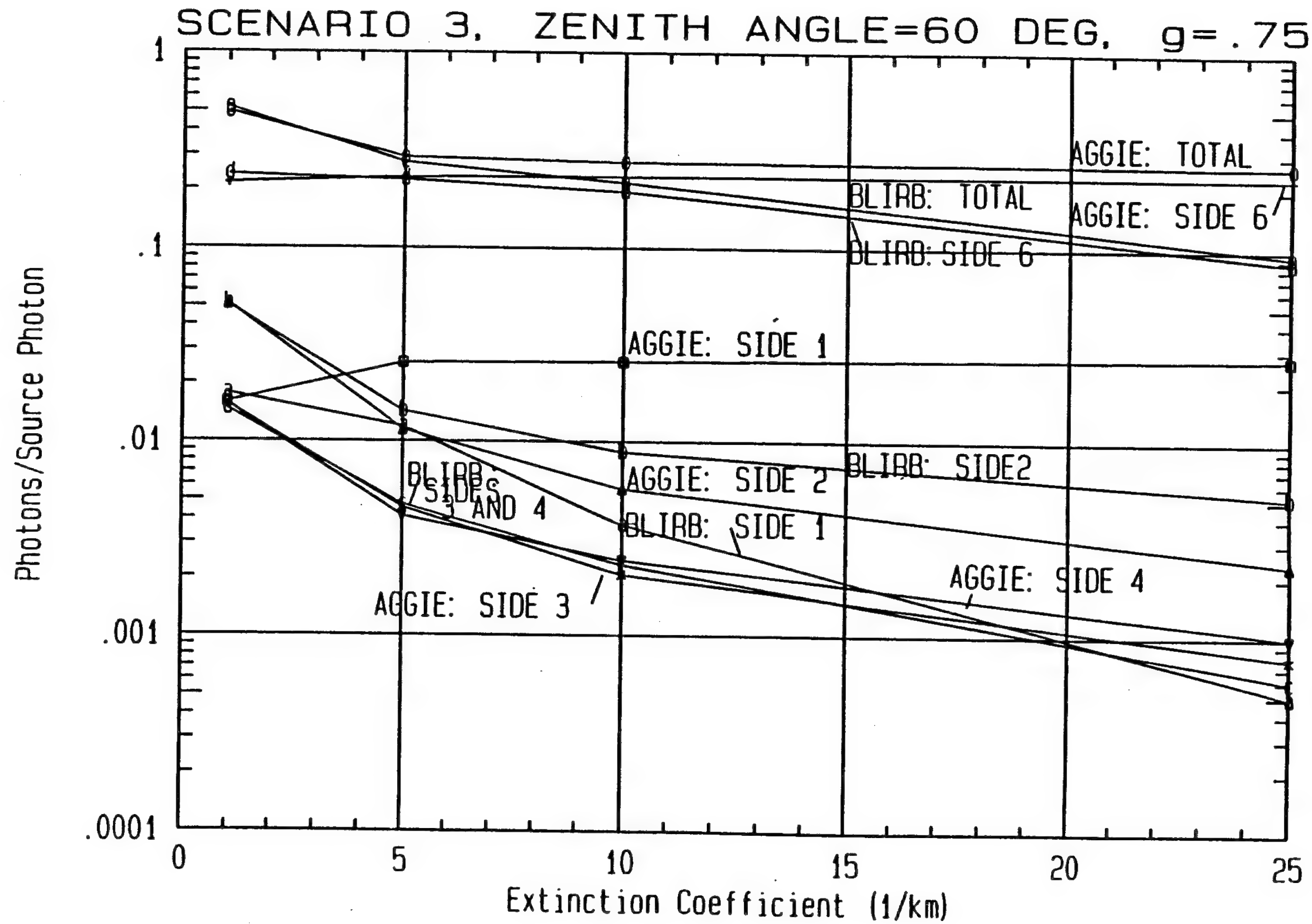

Figure 15. Fraction of incident photons exiting cloud sides and top.

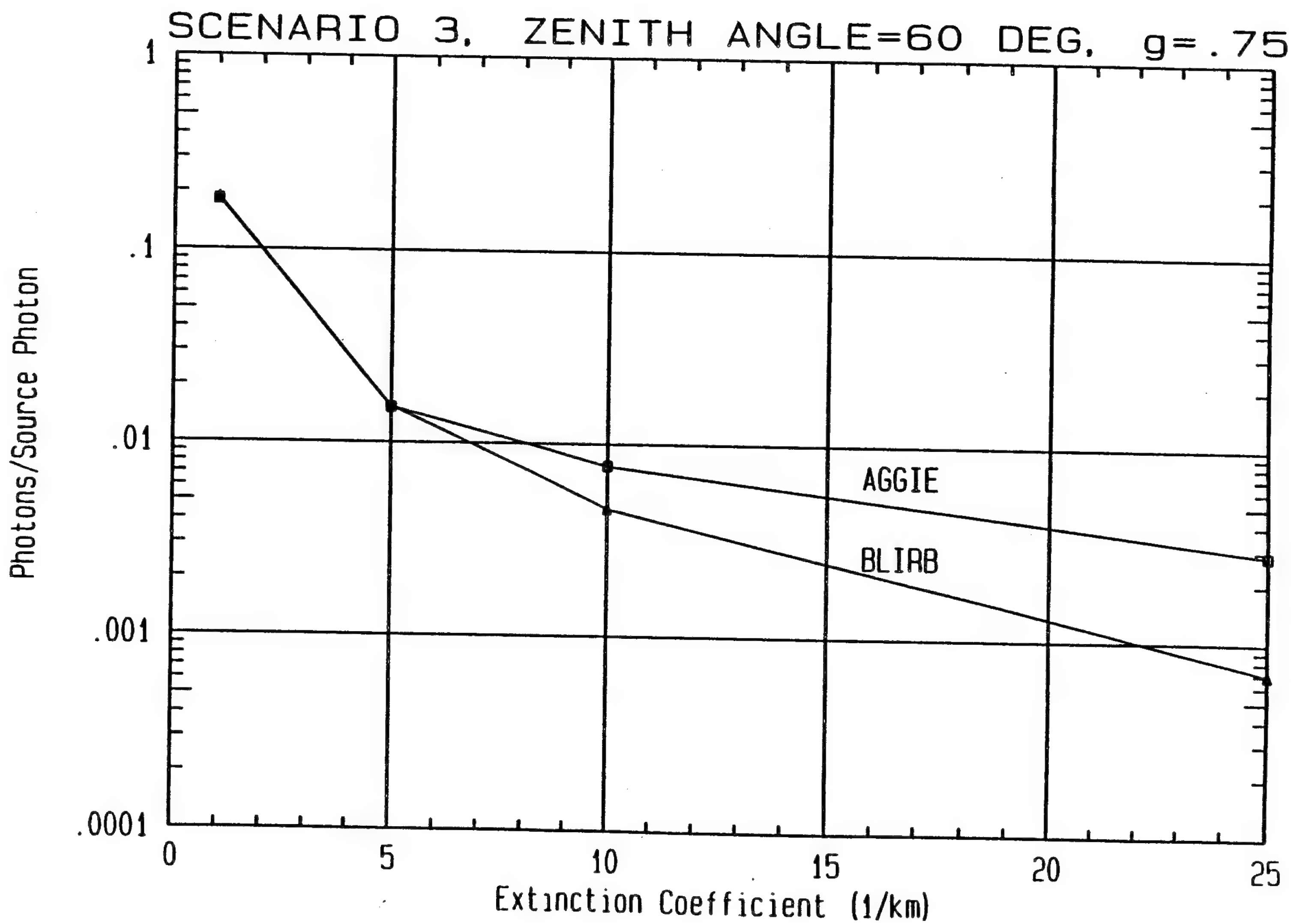

Figure 16. Fraction of incident photons exiting cloud bottom.

Table 16 shows a comparison between the AGGIE and BLIRB results for scenario 3 when the source zenith angle is 60°, the asymmetry parameter g = 0.0, and the single scattering albedo is 0.9. The AGGIE calculations of the leakage from side 1 as a function of the extinction coefficient are larger than those given by BLIRB. The AGGIE/BLIRB ratio data for side 1 is 1.77559, 6.40406, 9.71530, and 13.38367 for cloud extinction coefficients of 1.0, 5.0, 10.0, and 25.0 1/km, respectively. Because the source is incident to sides 1 and 6, it is expected that the photons/source photon leaking from side 1 would increase with an increase in the cloud extinction coefficient. The increase occurs with the AGGIE data for side 1, but not for the BLIRB calculation for side 1, as seen in figure 17. The photon leakage from side 6 is the largest contributor to the total leakage, with the BLIRB data being smaller than the AGGIE data for extinction coefficients of 10 and 25 1/km. Figure 17 shows the BLIRB data for sides 3 and 4 are always larger in magnitude than the AGGIE data.

Figure 18 shows a comparison between the AGGIE and BLIRB results for side 5 of the BLIRB space. The leakage from side 5, as given by AGGIE, is always larger than the BLIRB data for extinction coefficients greater than 1.0 1/km.

A comparison of the photon leakage for a zenith angle of 0.0° as calculated by AGGIE for scenario 3 when g = 0.75 and g = 0.0 reveals that more photons leak out of sides 1, 2, 3, 4, and 5 when g = .75 and less leak out of side 6 when g = 0.75. The total leakage when g = 0.0 is greater than the total leakage when g = 0.75. More photons leak from sides 2, 3, 4, and 5 when the zenith angle is 60.0° and g = 0.75 than when g = 0.0. Less photons leak out of sides 1 and 6 and the total leakage when g = 0.75 then when the zenith angle is 60.0° and g = 0.0.

Table 16. **Comparison of AGGIE and BLIRB data for photons leaking out of sides of cloud; zenith angle = 60.0°, g = 0.0, scenario 3[a] (photons/source photon)**

Side No.	Total Photon Leakage	% STD	BLIRB Data	AGGIE/ BLIRB
Extinction Coefficient = 1.0 1/km				
1	.52735−01	.38166+01	.0297	1.77559
2	.24469−01	.43710+01	.0434	.56380
3	.10830−01	.57259+01	.0131	.82672
4	.10445−01	.59058+01	.0132	.79129
5	.64455−00	.27158+01	.0662	.97357
6	.42510+00	.69410+00	.4368	.97321
Total	.58803+00		.6024	.97615
Extinction Coefficient = 5.0				
1	.61479−01	.31917+01	.0096	6.40406
2	.49912−02	.19671+02	.0088	.56718
3	.23929−02	.17462+02	.0037	.64673
4	.25202−02	.22531+02	.0037	.68113
5	.73598−02	.11608+02	.0059	1.25420
6	.43177+00	.11606+01	.4384	.98488
Total	.51055+00		.4701	1.08604
Extinction Coefficient = 10.0				
1	.64121−01	.46311+01	.0066	9.71530
2	.27242−02	.20426+02	.0022	1.23827
3	.13326−02	.30663+02	.0019	.70137
4	.10845−02	.20227+02	.0019	.49295
5	.31043−02	.14202+02	.0022	1.41146
6	.43134+00	.11377+01	.3581	1.20452
Total	.50371+00		.3729	1.35079
Extinction Coefficient = 25.0				
1	.65580−01	.39846+01	.0049	13.38367
2	.10702−02	.33202+02	.0005	2.14040
3	.45832−03	.66664+02	.0006	.76383
4	.47336−03	.54420+02	.0006	.78883
5	.12074−02	.31859+02	.0003	4.02467
6	.43091+00	.64392+00	.1261	3.41721
Total	.49970+00		.1330	3.75714

[a]Isotropic scattering

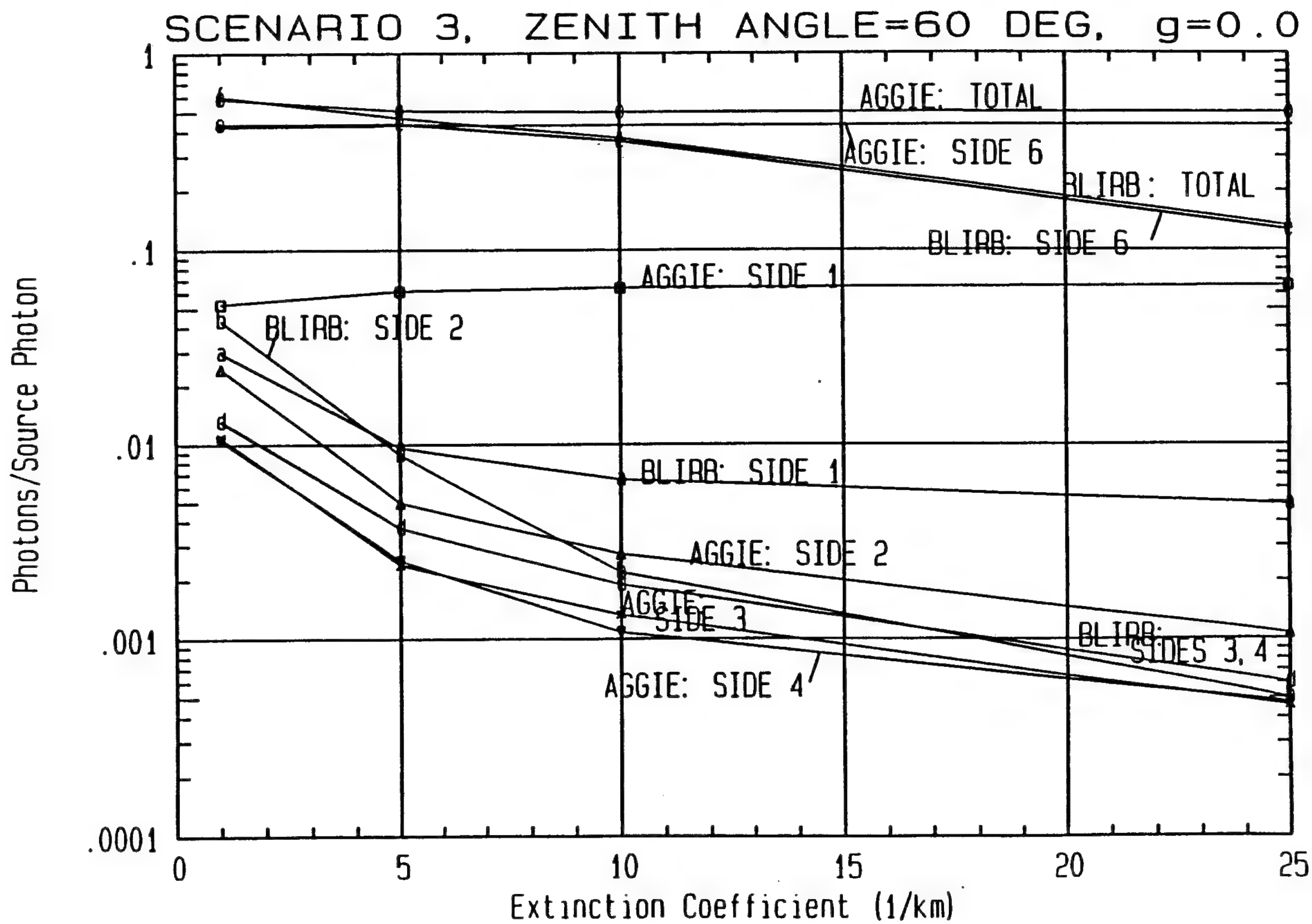

Figure 17. Fraction of incident photons exiting cloud sides and top.

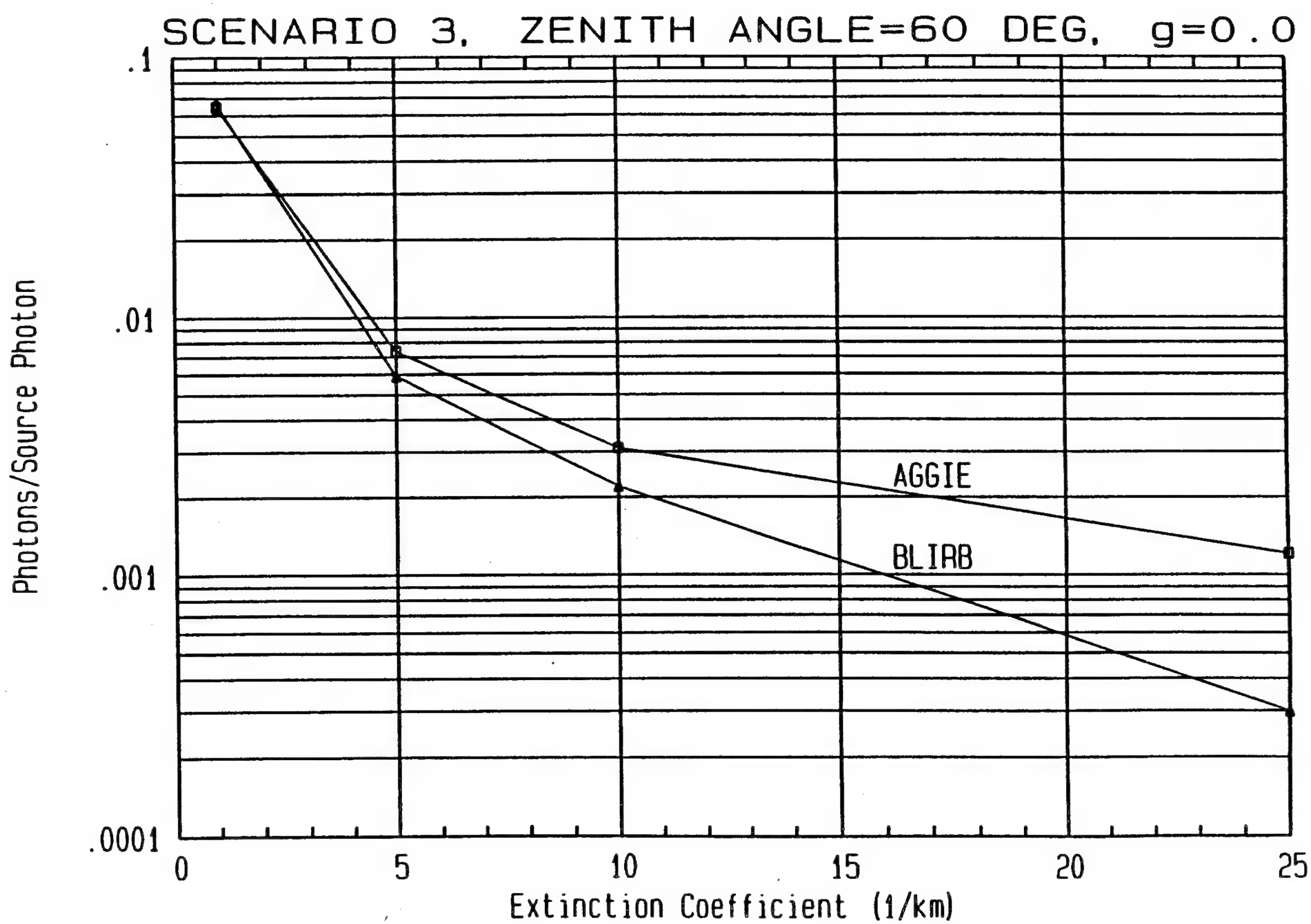

Figure 18. Fraction of incident photons exiting cloud bottom.

5. Conclusions and Recommendations

The BLIRB calculations for scenario 1 when the source zenith angle is 0.0° were found to agree rather well with the AGGIE calculations except for side 5 when the extinction coefficient is 5.0 and 10.0 1/km. When the source zenith angle is 84.3° for scenario 1, there were large differences between the AGGIE and BLIRB calculations for sides 2 and 6 where the AGGIE results were significantly higher in magnitude than the BLIRB results for extinction coefficients of 3.0 1/km and greater.

The AGGIE leakage data calculated for sides 1, 3, 4, and 6 for scenario 2 when the source zenith angle is 0.0° were significantly larger than the data for those sides that were given by the BLIRB calculations for extinction coefficients of 1.0, 5.0, 10.0, and 25.0 1/km. The AGGIE and BLIRB results for sides 2 and 5 differ by no more than 11 percent for extinction coefficients of 1.0, 5.0, 10.0, and 25.0 1/km. The BLIRB calculations of the total leakage for scenario 2 when the source zenith angle is 0.0° are in good agreement with the AGGIE calculations for those sides. It should be pointed out that the leakages from side 5 are 88.66 to 93.13 percent of the total leakage when the zenith angle is 0.0°.

When the source photons are incident at a zenith angle of 30° to sides 1 and 6 of the BLIRB space for scenario 2, the BLIRB results for sides 1, 3, 4, and 6 are significantly larger than the AGGIE results for those sides. The AGGIE and BLIRB results for sides 2 and 5 and for the total leakage are in good agreement.

For the source radiation incident at a zenith angle of 30.0° to sides 2 and 6 of the BLIRB space for scenario 2, BLIRB gave significantly larger leakages for sides 1, 3, 4, and 6 than did the AGGIE calculations for those sides. In general, the AGGIE and BLIRB data for sides 2 and 5 and the total leakage were in good agreement. The leakage from sides 2 and 5 represent more than 94 percent of the total leakage for extinction coefficients of 1.0, 5.0, 10.0, and 25.0 1/km.

The photon leakage from the 25 areas on the bottom of the BLIRB space for scenario 2 as given by the BLIRB calculations are in reasonably good agreement with the AGGIE calculations for zenith angles of 0.0° and 30°. The areas on side 5 that see uncollided source radiation are the same for the AGGIE and BLIRB calculations.

The BLIRB calculations for scenario 3 for a zenith angle of 0.0° and g = 0.75 agree with the AGGIE data for sides 1, 2, 3, and 4 within about 18 percent. The BLIRB data for side 5 agree with the AGGIE data for side 5 only the cloud extinction coefficient is 1.0 1/km. The BLIRB results for the leakage from side 6 is between about 8.5 to 24 percent of the results given by the AGGIE code for side 6. The BLIRB data for an extinction coefficient of 25 1/km is about 20 percent less than the AGGIE data for an extinction coefficient of 25 1/km.

When g = 0.0 and the source zenith angle is 0.0°, the leakage from side 6 as given by BLIRB is in fair agreement with the AGGIE calculations for extinction coefficients of 1.0, 5.0, and 10.0 1/km. For an extinction coefficient of 25.0 1/km, the AGGIE calculated leakage for side 6 is a factor of 1.836 larger than the BLIRB calculated leakage. The BLIRB data for sides 1, 2, 3, and 4 are as much as a factor of 2.25 to 1.18 greater than the AGGIE calculations for those sides. The BLIRB data for side 5 when the extinction coefficient is 5.0, 10.0, and 25.0 1/km significantly overpredicts the AGGIE data for side 5.

When the source zenith angle is 60° and g = 0.75, the BLIRB results for side 1 exceed the AGGIE data by factors of 2.1 to 54.3 as the extinction coefficient varies from 5.0 to 25.0 1/km. The leakage from side 2 as calculated by BLIRB is a factor of 0.987, 1.25, 1.55, and 2.20 greater than the AGGIE data and extinction coefficients of 1.0, 5.0, 10.0, and 25.0 1/km. For sides 3 and 4, the BLIRB data are in fair agreement with the AGGIE data for extinction coefficients of 1.0, 5.0, and 10.0 1/km. The BLIRB data for an extinction coefficient of 25 1/km and sides 3 and 4 are significantly less than the AGGIE calculated leakages for those sides. The AGGIE and BLIRB leakage data for side 5 are in good agreement for extinction coefficients of 1.0 and 5.0 1/km; but for extinction coefficients of 10 and 25 1/km, the AGGIE data exceed the

BLIRB data by factors of 1.66 and 4.06, respectively. For side 6, the AGGIE and BLIRB leakage data are in good agreement for extinction coefficients of 1.0 and 5.0 1/km; for extinction coefficients of 10.0 and 25.0 1/km, the AGGIE data exceed the BLIRB data by factors of 1.19 and 2.68, respectively. When the source zenith angle is 60.0° and g = 0.0 for scenario 3, the AGGIE leakages for side 1 are factors of 1.77, 6.40, 9.72, and 13.38 greater than the BLIRB results for extinction coefficients of 1.0, 5.0, 10.0, and 25 1/km. The AGGIE data for side 2 are factors of 0.56, 0.57, 1.24, and 2.14 greater than the BLIRB data for extinction coefficients of 1.0, 5.0, 10.0, and 25.0 1/km. Sides 3 and 4 contribute the least to the total leakage for all extinction coefficients considered, the AGGIE data are factors of 0.49 to 0.82 of the BLIRB data. The AGGIE data for side 5 are factors of 0.97, 1.25, 1.41, and 4.02 greater than the BLIRB data for extinction coefficients of 1.0, 5.0, 10.0, and 25.0 1/km. The AGGIE data for side 6 are factors of 0.97, 0.98, 1.20, and 3.42 larger than the BLIRB data.

The percent standard for the AGGIE calculations for each of the sides of the BLIRB space for scenario 3 is the smallest for the sides that make the largest contributions to the total leakage. Side 6 for zenith angles of 0.0° and 60.0° makes the largest contribution and has STDs on the order of 5.0 percent or less. The percent STDs for scenario 3 data usually increases when the magnitude of the leakage is a factor of 10 or more, which is smaller than the leakage for side 6. When side 6 is of the order of 0.1, the percent STD is usually less than 5.0 percent. When the leakage is of the order of 0.01, the percent STD is between 5 and 10 percent. If the photon leakage is of the order of 0.001 or less, the STD increases as the magnitude of the leakage decreases.

From the comparisons of the AGGIE and BLIRB results shown in this report for scenarios 2 and 3, the calculational methods used in the BLIRB code need to be examined to see if modifications to BLIRB can be made that would improve the BLIRB results for those scenarios. Further AGGIE calculations should be made to check the validity of BLIRB calculations for point sources, representing flares, and directional sources such as search lights and lasers. Further AGGIE calculations need to be made to check out BLIRB data for atmospheric emission sources.

References

Wells, M. B., *Monte Carlo Code for Evaluating the Boundary Layer Illumination and Radiation Balance Model BLIRB*, U.S. Army Research Laboratory, Technical Report ARL-CR-193, January 1995.

Zardecki, A., *Modification and Evaluation of the Weather and Atmospheric Visualization Effects for Simulation (WAVES) Suite of Codes*, Los Alamos Consulting, Technical Report for Contract No. DAALO3-91-C-0034, Delivery Order No. 1390, 3 June 1995.

Acronyms and Abbreviations

AGGIE	A Generalized Geometry Irradiance Estimator
BED	Battlefield Environment Directorate
BLIRB	Boundary Layer Illumination Radiation Model
STD	standard deviation
3-D	three dimensional

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